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ABSTRACT

This is the first interagency report on Federal environmental quality research and development programs that presents program descriptions, levels of funding, and analyses. Undertaken at the request of the Federal Council for Science and Technology, the study may be useful in identifying environmental quality research and development programs in various agencies and allow for better coordination between widely separate disciplines. Program activities were considered in nine areas: air quality; water quality; land quality (including solid waste); understanding, describing, and predicting the environment; protecting and enhancing the environment; alternatives to the use of pesticides; noise; radiation; and population. Funding levels are determined in each of the subject areas for fiscal years 1969, 1970, and 1971. Analysis of the Federal program was performed in terms of its balance, trends, priorities, gaps and overlaps, and future needs. A short summary, an analysis, and a table of funding by agencies for each of the subject sections are included in the main report. Full reports of the subject matter investigations are presented in the appendix. An overall summary of the analyses and specific recommendations relating to all reported Federal environmental quality research and development is also compiled. (BL)

ENVIRONMENTAL QUALITY RESEARCH AND DEVELOPMENT

a review and analysis of federal programs

Report of Ad Hoc Committee on
Environmental Quality
Research and Development of
The Federal Council for Science and Technology

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY

AUGUST 1971

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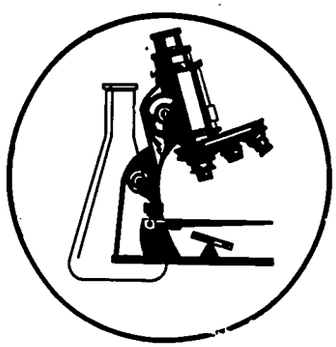

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Preface

This is the first interagency report on the Federal environmental quality research and development programs that presents program descriptions, levels of funding, and analyses. It is presented in accordance with Federal reorganizations including the Environmental Protection Agency and the National Oceanographic and Atmospheric Administration. The study was undertaken at the request of the Federal Council on Science and Technology. It is responsive to the requirements of the Council on Environmental Quality and the Office of Management and Budget to review existing programs and activities in this area. It is hoped that it will be useful in identifying the environmental quality research and development programs in various agencies and to provide better coordination between widely separated disciplines.

Environmental quality is one of the most pervasive issues facing the Nation today. It is the responsibility of the public, industry, and all levels of government. The Federal Government has responsibilities for acquiring new knowledge, and for developing methods and technology to prevent degradation and to improve and wisely manage the environment. Federal agencies are contributing to solutions of these problems, but available funds and manpower do not permit adequate coverage for all problems, so that relative priorities and balances must be established. Many reports have been published in recent years recommending the research and development in environmental quality that should be undertaken by the Federal Government. Available recommendations and analyses have been considered in this report in an attempt to identify trends, gaps, and overlaps.

The report has been made possible by the valuable assistance of Federal agency representatives and has been reviewed by all of the agencies involved. The Committee is grateful to its vice chairman, Dr. Harve J. Carlson who chaired the R. & D. analysis panel which organized, revised, and edited the report with the capable assistance of Dr. Wardelia W. Doschek of NSF and Mrs. Mary Higgs of USDA.

DALE W. JENKINS, *Chairman*
Ad Hoc Committee on Environmental
Quality, Research and Development

Contents

Introduction

The Federal Council for Science and Technology (FCST) established the ad hoc Committee on Environmental Quality Research and Development[1] in July 1970. The assigned functions of the Committee were—

- To continue to assemble information on the research and development activities of the Federal Government related to environmental quality.
- To carry out a special analysis of research and development in the Federal agencies and write a report for the Council on Environmental Quality and the Office of Management and Budget.

The Committee, with representation from the scientific segments of Federal departments and agencies, compiled narrative summary descriptions and fiscal data on the environmental quality research, development, and demonstration (hereinafter referred to as R. & D.) programs performed or supported by the Federal Government. Projects and task level activities were not reported individually but were included as part of programs. In general, more narrative is devoted to larger, more heavily funded programs. Some smaller programs of an innovative nature, however, have also been highlighted. The areas considered are air quality; water quality; land quality (including solid waste); understanding, describing, and predicting the environment; protecting and enhancing the environment; and special studies on alternatives to the use of pesticides; noise; radiation; and population. It is recognized that some of the material, which has been classified under any one of these areas, could just as logically have been classified under another of the areas. The Committee took into account previous studies of pollution R. & D. by the former Committee on Environmental Quality of FCST and more recent environmental quality special analyses conducted by the Office of Management and Budget.

The results of the Committee's survey to determine the level of funding for the subject areas considered in the report for fiscal years 1969, 1970, and 1971 are reported in table 1 (p. 3) and summarized in figure 1 (p. 2).

The present study had three specific objectives: (1) To identify and describe agency R. & D. activities in the above-listed categories; (2) to determine the funding levels for fiscal years 1969, 1970, and 1971; and (3) to analyze the Federal program in terms of its balance, trends, priorities, gaps and overlaps, and future needs. Special panels were formed to compile the program descriptions and to review and analyze the programs. An R. & D. analysis panel assembled, analyzed, and critically reviewed the entire report.

Full reports of the subject-matter panels are included in the appendix of this report. A short summary, an analysis, and a table of funding by agencies for each of the sections are included in the main report. An overall summary of the analyses and specific recommendations relating to all reported Federal environmental quality R. & D. are included in chapter 2.

Environmental quality was considered from such broad standpoints as pollution, environmental degradation, esthetics, recreation, resource management, space for living, wildlife habitat, and biological and physical systems or phenomena. Components of the environment were considered to be air; water; land (soil, minerals, etc.); biota (including man); and materials, devices, and structures. An underlying consideration for all aspects of the Committee's work was the need to maintain or manage surroundings and natural resources and systems essential for the long-range benefit of man and other living organisms. A primary consideration was the availability of sound

[1] The Committee on Environmental Quality of FCST was terminated in May 1970 in recognition of the new Council on Environmental Quality. However, the former Research, Development, and Demonstration Subcommittee was retained and the ad hoc Committee was formed with additional agency representatives.

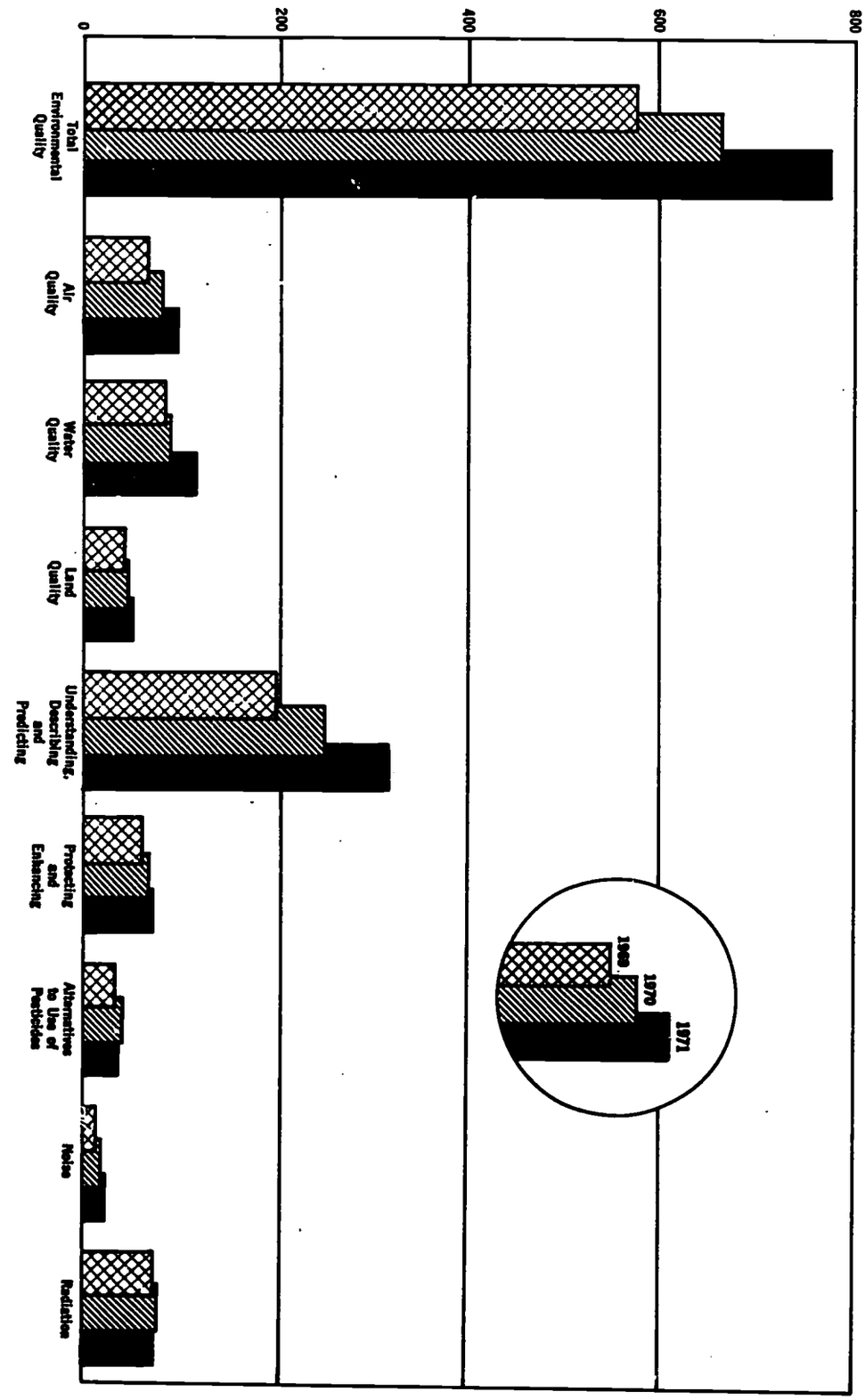


FIGURE 1.—FEDERAL R&D FUNDS
ENVIRONMENTAL QUALITY by Purpose, FY 1969, 1970, 1971

TABLE 1.—*Total Federal environmental quality program research and development—fiscal years 1969, 1970, and 1971, summary by purpose*

[Figures in millions of dollars]

Purpose	Fiscal year		
	1969	1970	1971
Air quality	62.51	79.06	93.92
Water quality	83.31	88.79	115.37
Land quality	42.99	44.71	50.94
Understanding, describing, and predicting the environment	199.49	249.99	323.52
Protecting and enhancing the environment	57.53	65.59	67.62
Special studies:			
Alternatives to use of pesticides	33.08	34.74	38.94
Noise	18.90	18.95	19.47
Radiation	74.29	77.43	77.37
Total	572.10	659.26	787.15

scientific knowledge about the effects of pollutants on living organisms and their environments.

This study did not attempt to summarize environmental quality R. & D. supported by non-Federal entities—State and other levels of government, other countries, industry, universities, State experiment stations, and foundations. The Committee is aware that a great deal of important and effective work is done by non-Federal organizations and recognizes that no overall evaluation of the Nation's total environmental R. & D. effort can be made without taking them into consideration. Such an analysis still needs to be made.

Capital investments in R. & D. facilities are not included. The closely related areas of pollution monitoring, industrial health, occupational health and safety, pollution control and technology, manpower requirements, legislation, regulations and enforcement, and all actual operations for environmental enhancement and surveys to understand the environment are not included. Funding for research on environmental quality in this report may differ from that reported elsewhere, because this report excludes such costs as building and operating research facilities, ship support, launch vehicles, satellites, and aircraft.

Reorganization of Federal agencies involving environmental quality occurred while this report was being written. Program and fiscal data for the Environmental Protection Agency (EPA established Dec. 2, 1970) and the National Oceanic and Atmospheric Administration (NOAA created Oct. 3, 1970) have been presented according to the present reorganizations. Fiscal data for programs transferred from other agencies are reported under EPA and NOAA as though they existed previously, to prevent complexities of data presentation.

Another important consideration not extensively covered in this report is the impact of closely related developments, research or otherwise, on environmental quality. There are technological, social, economic, and legal developments that could have as great an impact on the future of environmental quality as those research activities considered in this report. Information exchange is also necessary. These related activities might be appropriately classified as alternatives.

Typical examples are—

(a) Low-cost tunneling techniques that would offer mass transportation with closed-cycle or controlled air ventilation.

(b) Low-cost fuel cell or other power sources for home or industrial use that could eliminate a significant measure of pollution from wasted energy associated with centralized powerplant operations.

(c) Atomic fusion development offering what appears to be a relatively pollution-free energy source.

(d) Urban and rural land-use planning, which guides community development, to avoid or reduce natural hazards and constraints and to use and preserve environmental opportunities and amenities.

Another area only briefly discussed in the report is R. & D. programs on disposal of solid waste. Municipal solid waste is generated in this country at a rate of 6 pounds per capita per day—about a ton for every man, woman, and child in this country every year. By 1980, this rate is expected to increase to about 8 pounds per capita per day. To collect, transport, and dispose of this enormous quantity of urban refuse, this country spends more than $4 billion each year, and 80 percent of that amount is spent on collection alone. Increased emphasis must be placed on developing improved collection processes utilizing the techniques of systems analysis and other operations research tools in this area.

Concern about the quality of our environment is shared at the Federal, State, and local levels. Pollution, whether in the air, land, or water, has no boundaries and, therefore, becomes of concern internationally whether or not the countries share a common border, river, or sea. Our Nation is partici-

pating in several global R. & D. and monitoring programs and should participate in additional ones. All international programs of the Federal agencies on environmental quality R. & D. are not included in this report.

Environmental quality R. & D. programs of Federal agencies are coordinated by various mechanisms including interagency panels and committees of the Office of Science and Technology, and various commissions, interagency committees, task forces and task groups, and working groups, between various Federal agencies. Certain agencies pool their resources and provide each other with basic information. There are a number of information coordination systems such as the Science Information Exchange. Agencies also maintain multidisciplinary laboratories and centers, and fund joint programs or projects. Agencies frequently transfer funds to other agencies to carry out research programs and tasks. Memoranda of understanding agreements are signed between agencies to provide long-term mutual programs.

In addition to interagency coordination, the Federal agencies also have coordinating mechanisms with State and local agencies including joint programs and funding of programs. The Federal agencies give research contracts and grants to profit and nonprofit institutions including universities and consortia.

There is a very real need for additional intensive, intelligent R. & D. efforts in all areas of environmental quality. Of equally great importance, however, is the conscientious application and utilization of existing knowledge in the making of policy decisions and in the initiation of activities that may affect environmental quality.

The total Federal expenditures (obligations) in the fields of pollution control and abatement and environmental quality related activities for fiscal year 1971 were $6,005 million of which pollution control and abatement was $2,005 million based on surveys by the Office of Management and Budget and the R. & D. subcommittee, Committee on Environmental Quality, FCST. These reports show that the fiscal year 1971 obligations for research and development in the above fields were $856.5 million. In the present study, using different parameters and more detailed and updated information, the fiscal year 1971 obligations for R. & D. were $787.15 million. These studies show that the R. & D. programs are less than 15 percent of the total Federal expenditures in this field.

DEFINITIONS OF TERMS USED

Terms used in this report are defined as follows:

Research—The systematic pursuit and acquisition of information, knowledge, and understanding.

Development—The systematic conversion of the results of research into useful technology.

Demonstration—Operational or commercial-scale exhibits of designated subjects at selected locations and for specific objectives designed to depict new technology.

Environment—The surrounding or enveloping complex of physical, chemical, and biological conditions that may affect the survival and welfare of man and other living organisms.

Environmental quality—The degree to which constituent environmental conditions meet acceptable standards for human health, welfare, and the enjoyment of natural resources and amenities.

Pollution—A condition of air, water, or land characterized by the presence of materials in such form or quantity as to be potentially deleterious to health, injurious to plant or animal life, offensive to the senses, or otherwise socially unacceptable.

Ecology—The study of organisms and their relationships to each other and to the environment.

Ecosystem—A natural, identifiable, interacting network of organisms and their physico-chemical environment that constitute a subsystem of the biosphere.

AGENCY ACTIVITIES IN ENVIRONMENTAL QUALITY R. & D.

Atomic Energy Commission (AEC)

AEC's research and development responsibilities include achieving a more complete understanding of the mechanisms by which radioactivity arising from man's nuclear activities moves through and interacts with the natural environment. An extensive program in radiation biology is continuing to elucidate the biological and physical processes resulting from radioactivity in the environment and to adequately assess the effects of radiation injury and repair. Improved instrumentation for the detection, and measure of radioactivity in the environment is being developed. Immediate and long-term effects of acute and chronic exposure to radiation in terrestrial and aquatic ecosystems are studied. Improved methods of handling and disposing of radioactive wastes from the nuclear

energy industry are developed and tested. The program includes terrestrial, fresh water, marine, and atmospheric sciences. These vital research areas predate the current popular interest in environmental problems, and include studies dealing with interrelations of organisms and populations with their environment, with particular emphasis on the fate and effects of radioactivity within these ecosystems. Much of the support is for research on pathways, rates of movement, and distribution of radioactive substances in the natural environment and man's food chain, but many studies on effects of radiation on natural populations have also been supported. Some of the effort is necessarily devoted to baseline studies which establish the norm on which predictions may be made about fate and effect. In addition to increasing our understanding of radioactivity in the biosphere, these programs contribute much to basic knowledge about ecology, man's food chains, and other broad aspects of environmental science.

Corps of Engineers (CE)

CE[2] is concerned with the development of the Nation's water and related land resources, requiring detailed study of the effects of engineering works on the environment. Investigations are accomplished through a centralized research program and as part of studies of proposed construction projects. Impacts of engineering works on the terrestrial and marine environments are evaluated to develop design criteria and improve technology. Experiments are conducted in deep multipurpose impoundments to reduce stratification and improve temperature and stored oxygen levels. Studies of aquatic plant control are pursued to include methods of controlling aquatic plants in navigable streams and along coasts with emphasis on nonchemical methods. The Corps has responsibility for studying shore processes as affected by wind and wave actions, storms and other marine and atmospheric processes in order to preserve the national coastline. Studies are being conducted on the hydrologic cycle, general watershed hydrology, and effects of the atmosphere on regional areas in order to minimize the effects of floods.

United States Department of Agriculture (USDA)

USDA's responsibilities include research on the effects of air pollutants on forests, crops, and horticultural plants and on the prevention and control of agricultural and forestry sources of air pollution. A major continuing program includes the search for various safe and effective alternatives to pesticides and the development of selective and nonpersistent chemical pest controls. The Department has interests and responsibilities for alleviating adverse impacts of and on agricultural and forestry operations. Research is conducted on the development of outdoor recreation resources, on the protection and management of fish and wildlife habitat, and on the augmentation of fresh water resources. Ways are sought to improve esthetic aspects of man's environment through plants and systems for landscaping homes, green spaces, and countryside. A wide variety of projects relate to the structure, development, and functioning of natural ecosystems and to natural and man-caused impacts.

Department of Commerce (DOC)

DOC provides services related to pollution detection and abatement through the National Bureau of Standards. This Bureau provides evaluations of current measurement methods and of the results of research leading to improved techniques, in support of abatement programs of other Federal agencies, local government, and industry. The National Oceanic and Atmospheric Administration (NOAA) was created on October 3, 1970.[3] Current R. & D. contracts under the supervision of the Maritime Administration call for development of equipment and techniques and tanker design studies for minimizing pollution from oceangoing ships. The Department's major program in environmental quality R. & D. is dedicated to a more complete understanding of atmospheric and oceanic conditions and forces. Studies of hurricanes, tornadoes, and tropical storms result in earlier detection and more dependable forecasting. Long-term changes in national and world climate are studied with a view to improving local and regional weather forecasts. The Department

[2] U.S. Army.

[3] NOAA brought together in one agency the following elements: The Environmental Science Services Administration from the Department of Commerce; the Bureau of Commercial Fisheries, marine game fish research program, and Marine Minerals Technology Center from the Department of the Interior; the national data buoy development project from the Department of Transportation; the national sea grant program from the National Science Foundation; parts of the U.S. Lake Survey from the Army Corps of Engineers; the National Oceanographic Data Center, and the National Oceanographic Instrumentation Center.

conducts extensive experiments in modification of hurricanes, lightning, snow, hail, and other forms of precipitation. DOC also has responsibility for studies of the biological characteristics and requirements of living marine resources and conducts experiments on the effects of pollutants on marine ecosystems to benefit the sports fishing industry.

Department of Defense (DOD)

DOD's R. & D. program includes finding ways to reduce the emissions of undesirable exhaust constituents through improved combustion efficiency of military engines and modification of fuels. Contributions of military installations and ships to water pollution are minimized by better methods of sewage treatment, chemical effluent reduction, and toxic waste decontamination. New concepts, designs, and methods of construction are being tested to prevent erosion and sedimentation. Methods of preventing and controlling pollution from oil spills are also under study. The Department maintains a large program of atmospheric and oceanographic research aimed primarily at the understanding and modification of various severe storm phenomena. Possibilities of reducing noise from aircraft, particularly jet engines, are being investigated.

Department of Health, Education, and Welfare (HEW)

HEW's research programs provide data useful in assessing the human health hazard of a variety of materials. These data can be used to develop criteria and standards for food safety and environmental quality. The acute and chronic toxic effect of a variety of environmental components on the general population are assessed, and measurable parameters are being sought that can be used to predict toxicity in man. The materials receiving greatest attention in this program fall into the following categories: (a) Pesticides and agricultural chemicals; (b) air pollutants, including synthetic smog, metal oxides, and airborne dusts; (c) pharmaceutical agents; (d) industrial chemicals; (e) food constituents, additives, and contaminants; (f) natural products, particularly myotoxins; (g) metals and metallo-organic compounds; and (h) tobacco and related products. This program has had a major emphasis over the past several years in the area of pesticides, since knowledge gained from research on pesticide residues in foods aids in establishing the chemical identity of residues and their conversion products, developing improved techniques for measuring residue amounts, and tracing the metabolism of pesticides in biological systems. Soil and plant interactions with pesticides are also under study. These efforts are devoted to generating a body of information which will assist in drawing conclusions about a central and recurring theme of this report: "The Impact of the Environment on Man."

Department of Housing and Urban Development (HUD)

HUD's research and demonstration program contributes toward enhanced urban environmental quality by improving the knowledge base and techniques for community environmental planning, management, development, and redevelopment. The focus is upon the effects of the physical environment or the social environment and in community and personal needs. Support is provided for a wide range of projects related to local and regional planning, infrastructure investments (public facilities and services) and housing, public buildings, and other institutional construction. The diverse projects supported include such subjects as methods for: environmental planning (earth science focus), noise abatement, waste management (solid and liquid), energy provision, earthquake hazard reduction, subsidence prevention over abandoned mines, accommodating transportation facilities to the environmental multiple use of utility trenches and tunnels, and efficient deployment and distribution of public utilities and services.

Department of the Interior (DOI)

DOI's improved ore-smelting and coal-processing techniques are resulting in more complete removal of sulfur and other constituents, which reduces the level in stack gases. Methods of converting coal to other fuels having lower air pollution potential are being tested. Water quality programs are concerned with upgrading water for municipal, industrial and agricultural applications. Better methods of measuring dissolved and suspended inorganic, organic, and biological materials and heat are being used. The movement of these materials through the hydrologic system is being explained. Research in waste treatment is directed at methods of improving the quality of effluents and reducing processing costs. The Department also maintains research projects on reclamation of metal scrap, recycling of municipal refuse,

and stabilization and revegetation of industrial waste piles. DOI conducts studies on the origin, occurrence, and distribution of mineral resources and makes national land and mineral resource surveys. It has similar responsibilities for surface and underground water resources. Experiments on precipitation modification have reached the pilot test stage, and operational effectiveness is now being evaluated. The life processes, habitat requirements, natural enemies, diseases, impacts of environmental modifications, pollution, and techniques for improved management of fish and wildlife resources are being studied.

Department of Transportation (DOT)

DOT carries out investigations of air pollution in airport areas to provide the basis for environmental quality standards. DOT is also concerned with the development of fog dispersal systems for airport safety. Experiments in improved surface transportation system design, location, and structure will lead to reduced noise and air pollution. Other research in the Department is directed toward prevention of shipboard water pollution, more effective ways of detecting and tracing the source of pollutant concentrations in coastal and inland waters, and the development of oil spill and waste control equipment.

Environmental Protection Agency (EPA)

EPA was established within the Executive Branch on December 2, 1970.[4]

The R. & D. mission of EPA is to develop, test and demonstrate effective techniques for combating air, water, and land pollution by elucidating the critical relations among pollutants, forms of pollution, and control techniques. Through its research EPA determines the impact of air pollutants on plants, animals, and structures, and it provides the scientific basis for air quality criteria and standards. The capability for measuring and monitoring air pollutants will be improved through developing more sensitive and reliable instruments and techniques. The principal atmospheric processes that are affected by major air pollutants will be characterized. In the realm of water quality, EPA develops and demonstrates effective and economically practical technology for the treatment of specific pollution problems wherever possible through renovation and reuse of waste waters. EPA also provides a sound scientific basis for regulatory action, including the setting of water quality standards, through the development of knowledge and techniques for detecting, identifying, and quantifying pollutants, determining their fate in the water environment, and evaluating their effects on water use. EPA is also seeking better ways of reducing, recovering, and recycling useful products from waste materials.

The National Aeronautics and Space Administration (NASA)

NASA in carrying out its responsibilities for space research and applications and the advancement of aeronautics and space technology, has a number of programs that may contribute to environmental R. & D. These include work associated with the reduction of air pollution from aircraft engines and work on spacecraft life support systems which can contribute to the reduction of water pollution. A major program in aircraft noise abatement includes research and development aimed at a reduction in the noise generated, research promising a reduction in the noise impinging on the community, and research to aid the understanding of human response to noise. The meteorology program provides the satellite and instrumentation technology to support NOAA in its responsibilities for understanding the atmosphere, predicting weather, and establishing a basis for weather modification and climate control. The aeronomy program contributes to an understanding of the upper atmosphere. The earth resources survey program develops the efficient application of remote sensing technologies from aircraft and spacecraft to the needs and problems of the user community—the Federal, State, and local line organizations charged with earth resources responsibilities

[4] EPA brings together in a single organization the following Federal pollution programs formerly existing in separate agencies and in an interagency council: The Federal Water Quality Administration (FWQA) from the Department of the Interior; the National Air Pollution Control Administration (NAPCA) from the Department of Health, Education, and Welfare (HEW); parts of the Environmental Control Administration (ECA)—Bureaus of Solid Waste Management, Water Hygiene, and part of the Bureau of Radiological Health—from HEW; the pesticides research and standard-setting program of the Food and Drug Administration (FDA) from HEW; the pesticides registration authority from the Department of Agriculture (USDA); the authority to perform general ecological research from the Council on Environmental Quality (CEQ); certain pesticide research authority from the Department of the Interior; the environmental radiation protection standard-setting function from the AEC; and the functions of the Federal Radiation Council (FRC).

(agriculture, forestry, geology, hydrology, oceanography, land use planning, environmental management). The geodetic satellite program contributes to an understanding of the figure of the earth and to the dynamic processes governing the earth's activity.

The National Science Foundation (NSF)

NSF supports a broad spectrum of programs relating to the environment. The projects included in this report are only those programs whose specific objectives are related to or have a direct application to environmental quality. Examples of currently supported air pollution projects are fundamental investigations on combustion processes, long-term strategies for urban air quality, sources and movement of lead contamination, and determination of sulfur oxide and ozone levels that affect photosynthetic rate. In the area of water quality, support is provided for research on eutrophication processes, biogeochemistry of heavy metals, benefit-cost models of waste disposal systems, and basic investigations of heat transfer mechanisms. A diverse program in oceanic ecology includes such projects as ocean-atmospheric interactions, chemical oceanography, and polar environmental systems. NSF funded work in basic atmospheric physics supports weather modification research by a number of agencies. Of great scientific interest and importance is the international biological program (IBP) supported in large part by NSF. The Research Applied to National Needs (RANN) program supports a variety of environmentally related investigations in addition to other work. Other ecological research includes intensive studies on local or specialized plant and animal communities.

The Smithsonian Institution (SI)

SI through its astrophysical laboratory studies solar radiation, atmospheric dynamics, and the heat balance of the earth. The mobility of the earth's surface is being investigated, and attempts are made to relate such movements to the occurrence of earthquakes, volcanic activity, and other massive geophysical changes. The adaptability of the human species to rapid and severe environmental changes is being explored. Other Smithsonian programs establish ecological baseline data on plants and animals, examine natural regulatory systems and their effects on growth of living organisms, and conduct research on a variety of pollution problems.

The Tennessee Valley Authority (TVA)

TVA includes environmental research and development as part of its mission of comprehensive and unified development of the resources of the Tennessee Valley region. These efforts help solve environmental problems arising from or associated with resource use and development. TVA conducts research and development related specifically to water resources development, electric power supply and use, fertilizer and munitions development, and general resources development. This includes research on the effects of heated water discharges on stream temperature regimes and on downstream water uses, studies of river basin management to enhance water quality, pollution potential of agricultural fertilizers, reaeration of releases from storage impoundments to improve dissolved oxygen, research on the disposal of solid wastes, sulfur recovery from powerplant stack gases, strip mine reclamation development, and feasibility studies of joint facilities for treatment of wastes from several industrial plants.

Summary and Recommendations

This chapter highlights the crucial parts of the expanded analyses in the chapters that follow. To permit cohesion and unity without sacrificing brevity, it is organized into a short discussion of each of these chapters, followed by a list of recommendations that are common to most or all components of the total report. No single component of the environment is independent of others. For example, research and development (R. & D.) directed predominantly toward land quality also impinges on air quality and water quality. This interdependence is treated to some extent in chapters that follow and more completely in the appendices. The reader should refer to the appropriate chapter and appendix for a thorough treatment of a given subject.

Noise (app. 7) and radiation (app. 8) are not dealt with in the "media" chapters but are considered as separate topics. Similarly, the alternatives to the use of pesticides (app. 6) and population are regarded as sufficiently distinct to justify separate treatment as a special study.

While this report highlights the Federal R. & D. effort in environmental quality, it should be pointed out that conducting R. & D. in and of itself does not improve the quality of the environment. Effective educational and abatement-control programs that seek to apply the knowledge gained through research will continue to be required. Strong Federal leadership is essential to bring about the environmental enhancement we seek.

The funding for the total Federal environmental quality R. & D. program is summarized in figure 2 (p. 10). Table 2 (p. 12,13) presents the funds which were reported by each Federal agency in the subject areas covered by the chapters of this report. The fiscal years 1969, 1970, and 1971 are considered.

GENERAL RECOMMENDATIONS

A few major recommendations have been found to apply to many or all of the areas considered in this report. Some of them will be reiterated in the chapters for which they are particularly crucial. These recommendations that warrant special emphasis are the following:

1. *Program planning must be improved.*—This includes better evaluation of problems and establishment of priorities in terms of needed support for action programs, and more precise definition of specific research goals. Research on pollutants should give first emphasis to those that endanger man's health; second consideration to those affecting his welfare and the environment.

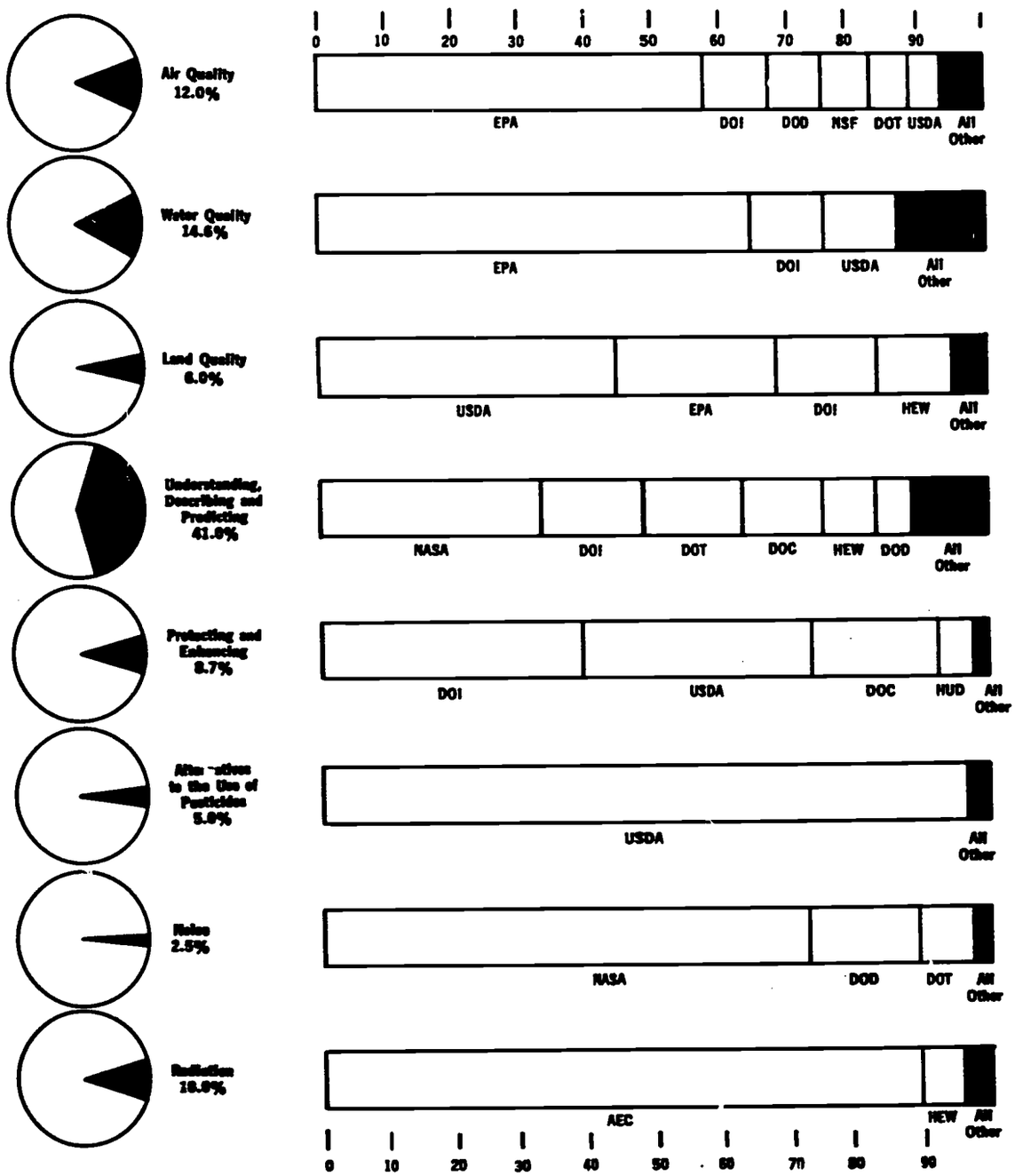
2. *Program coordination must be strengthened.*—Some mechanisms for coordination already exist. In many areas of environmental quality, however, improvements must be made including better mechanisms for intraagency and interagency collaboration and joint planning, closer cooperation at the project level, multidisciplinary action including wider and more effective use of interdisciplinary teams, and better coordination in instrument development.

3. *Application of research results must be accelerated.*—Existing knowledge must be more promptly and effectively disseminated, organized, tested, and put into use to solve important problems.

4. *Modeling and systems analysis procedures must be fully utilized.*—Increasingly sensitive, versatile, and powerful analytical tools are becoming available and should be adapted more skillfully and

FIGURE 2.—FEDERAL R&D FUNDS

ENVIRONMENTAL QUALITY by Purpose and Agency, FY 1971



imaginatively to solution of complex environmental problems, including socioeconomic aspects.

5. *Better waste disposal systems must be devised.*—Unregulated use of bodies of water for dumping municipal and industrial wastes is at an end. Alternative approaches, such as land disposal and recycling systems, must be developed and tested.

Air Quality

The major trend in research related to air quality is toward greater Federal participation in the development of prevention and control technology. Two-thirds of the more than $200 million total Federal expenditures on air quality R. & D. over the past 3 years have been on prevention and control.

Prevention and control of air pollution from mobile sources has been given high priority by Federal agencies. This is, in part at least, in response to the President's mandate in his February 1970 environmental message to develop "***an unconventionally powered, virtually pollution-free automobile within 5 years." Emission standards for mobile sources have also been established. Technology being developed for controlling pollution from other mobile sources, especially aircraft, will also help solve the automotive engine problem. Another high priority area is the development of control technology for stationary sources, particularly fossil-fueled electric power generating plants.

The necessity for more sensitive reliable measuring and monitoring instrumentation and techniques is recognized by the agencies reporting activities on this problem.

No obvious examples of unnecessary program duplication were found. EPA, supporting more than 60 percent of the total Federal funding for air quality R. & D., has a major responsibility in this regard, which it is able to exercise through its interagency fund transfers. Parallel efforts can be complementary or supplementary if they are planned that way. Interagency committees are useful and often essential tools, but it cannot be assumed that their existence automatically insures adequate and continuing coordination at the project level.

A number of the air quality R. & D. activities reported here have effectively mobilized diverse research talents in a team approach to problem solution. This is particularly important in dealing with the private sector. Good use is also made of industrial hygiene research findings in helping identify and evaluate potentially hazardous air-quality conditions.

An innovative and potentially productive project is planned for St. Louis, Mo., where the total air pollution problem of a single city would be studied in depth. An integrated effort involving Federal and State agencies, universities, and other groups would explore the chemical, meteorological, and biological ramifications of air quality. The Committee believes this is an excellent approach and recommends that it be carried out.

The utility of modeling systems for predicting the movement and concentration of pollutants is generally recognized. However, the measurement capability and sophistication necessary to deal with the complex forces involved are not yet available. Some modeling systems and field test results currently in existence may be applicable to modeling and predicting the movement of pollutants and airborne toxic materials. Particularly needed are high-accuracy sensing devices, better measuring methods for critical atmospheric parameters, and development of photochemical models.

There is insufficient emphasis on interactions and effects of mixtures of air pollutants. A more complete understanding is needed of the transformations, synergisms, and fate of airborne chemicals. Similarly, control technology for pollutant mixtures requires greater attention.

Basic and applied economics research, including cost-benefit studies, on air quality maintenance and improvement is needed.

Recommendations applicable to air quality are listed below:

- Assure interagency coordination to avoid unnecessary duplication of R. & D. effort.
- Implement an integrated attack on the air-quality problems of a metropolitan area.
- R. & D. program priorities should be more rigorously established on the basis of needs of action programs and pollution-control agencies.
- Utilize modeling systems to study individual and combined effects of pollutants.
- Insure adequate transition from R. & D. to operational programs to get new knowledge and technology applied promptly.

Water Quality

Research on water quality is now focusing on widening the known research base and on increasing efficiency and reducing costs of known processes. Particularly needed is a greater awareness of knowledge already available and not being used, and a more systematic and determined effort to organize

TABLE 2.—*Total Federal environmental quality program research and development*[1]

[Figures in millions of dollars]

Agency	Air quality			Water quality			Land quality			Understanding, describing, and predicting the environment		
	1969	1970	1971	1969	1970	1971	1969	1970	1971	1969	1970	1971
AEC				0.85	1.49	3.25	0.05	0.03	0.03			
CE	1.31	0.25	0.04	.38	.52	1.29	.10	.12	.16	5.50	6.70	8.40
USDA	3.90	4.43	4.69	9.96	11.54	12.04	20.64	21.37	21.41	9.89	10.93	13.89
DOC	1.65	1.74	1.84	.61	.63	.94	.10	.20	.20	22.90	26.20	38.90
DOD	8.26	7.33	7.52	.66	1.03	1.13		.10	.20	9.89	18.07	18.61
DOI	5.38	6.38	9.28	11.50	11.59	13.17	6.80	7.30	7.19	40.22	44.43	49.66
DOT	2.60	6.48	4.81	.80	4.27	4.00	.01	.01	.01	3.00	2.30	2.50
EPA	33.97	45.48	54.65	55.09	53.70	75.02	8.19	8.99	11.40			
GSA	0	.11	2.08									
HEW	.20	.34	.23				6.10	5.30	5.60	27.30	23.60	24.60
HUD				.10	.10	.10						
NASA	.45	.56	1.70	.70	.98	1.28				46.08	73.70	107.04
NSF	4.59	5.77	6.89	1.95	1.99	2.15	.80	.99	1.64	20.11	34.76	48.52
SI										5.60	9.30	10.40
TVA	.20	.19	.19	.71	.95	1.00	.20	.30	.10			
Total	62.51	79.06	93.92	83.31	88.79	115.37	42.99	44.71	50.94	199.49	249.99	323.52

[1] Funding for research on environmental quality in this report may differ from that reported elsewhere, because this report excludes such costs as building and operating research facilities, ship support, launch vehicles, satellites, and aircraft.

and apply such knowledge to the solution of important problems.

Several agencies with no previous commitment to water quality research are now becoming involved, in part because of their responsibilities for solving water quality problems which originate from their own activities. Other agencies for which water quality research has long represented an important but limited part of their total R. & D. are now giving it considerably more emphasis. Such broadening of concern could be expected to produce some overlap of research activities. The program descriptions provide evidence of apparently uncoordinated duplicative research. The extent to which this represents unnecessary duplication is difficult to determine. However, there seems little doubt that stronger and more effective interagency and intraagency coordination is needed.

More intensive use of coordinated interagency efforts and multidisciplinary team approaches based on analyses of total systems are also desirable. Federal water quality research has benefited from the competence found in industry, but the degree of industrial collaboration may not be adequate. In any event, university and industry cooperation should be solicited on a more systematic basis.

All broad areas of water quality problems were found to receive some R. & D. coverage. However, for many important problem areas this coverage is seriously inadequate. More reliable water quality criteria for heavy metals, synthetic organic compounds, and other specific pollutants are needed. Baseline data gathering, including monitoring techniques, could be improved in terms of geographic coverage and the number of toxic substances being measured. A great deal remains to be known about the biologic effects of water temperature and temperature changes under field conditions. More thought should be given to finding beneficial uses of thermal effluents. The role of sediments in streambank and channel erosion needs to be more clearly defined. Increasingly widespread salinity in surface drainage waters, and the contributions of plant residues and animal wastes to nutrient enrichment pose problems that have not had adequate research attention.

Innovative approaches to waste treatment that will remove toxic metals and other harmful materials are urgently needed. Prevention of discharge of toxic materials is urgently required. Alternatives to the use of streams, lakes, and oceans for discharging municipal wastes and industrial effluents must be developed and tested. The possibilities of disposing of such materials on forest and agricultural soils for recycling have particular promise.

Mathematical modeling of water quality situations is not yet fully utilized although it appears to offer

summary by various Federal agencies and purpose, fiscal years 1969, 1970, 1971

[Figures in millions of dollars]

Agency	Protecting and enhancing the environment			Special studies									Total		
				Alternatives to the use of pesticides			Noise			Radiation					
	1969	1970	1971	1969	1970	1971	1969	1970	1971	1969	1970	1971	1969	1970	1971
AEC										68.67	70.70	69.19	69.57	72.22	72.47
CE				0.20	0.30	0.30							7.49	7.89	10.19
USDA	20.27	21.62	23.31	32.05	33.64	37.71							96.71	103.53	116.11
DOC	14.22	15.16	13.15										39.48	43.93	55.03
DOD							2.31	4.71	2.82	1.15	.83	.83	22.27	32.07	31.11
DOI	22.27	23.00	26.59										86.17	92.70	105.89
DOT	0	.65	.75				2.18	2.56	1.73				8.89	16.27	14.80
EPA											1.11	2.36	97.25	109.28	143.43
GSA													0	.11	2.08
HEW							.05	.10	.20	4.25	4.50	4.67	37.90	33.84	35.30
HUD	.77	2.09	3.68				.12	.08	.10				.99	2.27	3.88
NASA							13.88	11.35	14.47				61.11	86.50	124.49
NSF	0	3.07	.11	.83	.80	.90	.06	.15	.15	.22	.29	.32	37.56	47.82	60.68
SI													5.60	9.30	10.40
TVA													1.11	1.44	1.29
Total	57.53	65.59	67.62	33.08	34.74	38.94	18.90	18.95	19.47	74.29	77.43	77.37	572.10	659.26	787.15

great promise. Modeling systems are rapidly becoming more sophisticated and can accommodate an increasingly large number of variables. Systems analysis has a similar potential especially for waste-recycling studies. The necessity for maintaining a balance between increasing refinements of modeling systems and improving the base of scientific knowledge about parameters that feed into those systems should be kept in mind.

Recommendations applicable to water quality are listed below:

- More effective methods and more positive implementation of intraagency and interagency research program coordination must be achieved.
- The total system approach to water quality problems, involving close Federal-State-industry cooperation, should be more widely utilized.
- Determined and well-organized efforts should be made to identify and apply knowledge about water quality control that is already available.
- Greater emphasis should be given to developing improved waste treatment and alternative waste disposal systems.
- More attention to the development of modeling systems is strongly encouraged.
- High priority should be given to the following research needs:
- Baseline data with broader geographic coverage and representing a greater number of toxic materials.
- Water quality criteria for specific pollutants.
- Thermal effects on aquatic life.
- Recycling of municipal, industrial, and thermal effluents on the land and in the air.
- Prevention and control of salinity and other mineralization.
- The role of plant residues and animal wastes produced by agricultural activities in eutrophication.

Land Quality

Land is a vital resource that cannot be permitted to deteriorate. Today, much attention is being given to reducing the pollution of air and water whereas relatively little is being given to reducing pollution of the land. Standards have been established for permissible levels of some pollutants; standards for others are being developed. Restrictions on pollutants of air and water have an immediate effect on land quality. For example, restrictions on burning to improve air quality require alternate methods for disposal of wastes, such as cotton gin trash, slash from logging operations, and the organic components of junked cars. Improved water-quality standards require alternate disposal methods for wastes, such

as sewage sludge and effluents from industrial processing.

The social and economic problems associated with the collection treatment and disposal of municipal refuse are assuming gigantic proportions. A more vigorous, coordinated, and imaginative approach to their solution is mandatory.

Because of the increasing restrictions on pollutants of air and water, there will be mounting pressures on land as a disposal site. However, land has a finite capacity for absorbing and assimilating wastes, and ground water quality can be adversely affected. Integrated planning and intensified research are mandatory requirements if the esthetic qualities and productivity of our land are to be improved, or even maintained.

Disposal of animal wastes and sewage sludge on land can be expected to increase. The effects especially the long-term ones, of repeated applications of animal and human wastes on the chemical, physical, and biological characteristics of the soil are not known. Accumulation of heavy metals from such practices is probable. Disposal on land of forest and crop residues pose some of the same problems as do animal and human wastes. Information is now inadequate to understand the biophysical and biochemical relationships that occur during residue decomposition.

Mineral and organic junk and urban refuse are a blight on the landscape. Studies are underway to improve sanitary landfill methods and to develop improved recycling technology.

Refuse from mining and milling operations and denuded land resulting from strip mining contribute to the deterioration of land quality. R. & D. in this field involves the recovery of valuable materials from mining and milling operations and the revegetation of strip mining sites to improve esthetic quality and habitat for wildlife and to provide additional areas for recreational use.

With increasing pressure on land for the disposal of various wastes, problems will become more severe. Thus, it is critically important that a national land policy be developed in terms of local, regional, and national planning. Only through such a concerted effort can the quality of our land be maintained.

Recommendations applicable to land quality are:

- Develop a national land use policy.
- Mount a more aggressive and innovative attack on municipal refuse problems.
- Increase emphasis on recycling of waste materials.

Understanding, Describing, and Predicting the Environment

R. & D. in this broad area includes (1) ecology and related research, (2) environmental observation and measurement for describing and predicting weather and ocean activities, (3) impact of environment on man, (4) locating and describing natural resources, (5) surveys to describe the physical environment, and (6) weather modification.

An appreciation for ecologic concepts is increasing rapidly. But the total effort is fragmented among many agencies with different missions and responsibilities. Coordination of ecological investigations is critically needed to permit identification of priorities and to provide the knowledge for asking critical questions. It is recommended that a special critical analysis be made of all ecologic research projects supported by the Federal Government regardless of the subject area in which it is classified.

Some R. & D. which is carried out by Federal agencies and reported elsewhere could have been included in this chapter.

Describing and predicting weather and ocean activities are very complex undertakings. If their utility and accuracy are to be increased, expanded research will be needed, particularly for an understanding of atmospheric and oceanic circulations. Only through increased research and monitoring can the interaction of land-sea-air be understood and ultimately predicted. Monitoring systems must be established and integrated to determine pollutant levels and their effects on estuarine and marine organisms.

The study of increasing chronic effects of specific environmental pollutants on man, and on other selected organisms, should be intensified. In a broader sense, the impacts of long-term environmental change also need investigation.

Greater efficiency is required in making surveys for locating, describing, and monitoring natural resources. It is recommended that the potential of remote multispectral sensing be fully developed for natural resource surveys. Particularly needed is research on the correlation of ground truth with spectral signatures so that identification can be automated.

Modeling systems appear to have promise for predicting earthquakes and shoreline changes.

The Federal weather modification program is well coordinated and has made great progress in developing the fundamental information needed to permit significant results. It is recommended that

extensive applied research be coupled with research into the legal, social, and economic implications. Precipitation management, reduction of damage from hail, lightning, and violent storms, and improvement of visibility in fogs are possible if funds are committed to achieve operational technology. Systems approaches and mathematical modeling are required components for success.

Protecting and Enhancing the Environment

The activities reported under this category lack the common orientation of other chapters of this report. It includes (1) environmental systems, (2) fish and wildlife resources, (3) recreation resources, (4) rural and wildland environment, (5) urban and suburban environment, and (6) water resources. Also, problem areas described often impinge upon the concerns of other chapters.

The overall effectiveness of research could be improved by broader application of the principles of good planning. Problems should be more systematically defined and evaluated and should be selected for study on the basis of explicit and valid criteria, with priorities established for specific and attainable goals. An appropriate balance should be sought between short-term projects to correct existing problems and longer term activities to prevent future problems. Positive action should be taken to insure planned coordination and cooperation at the project level both within and between agencies through mutual funding. Multidisciplinary teams should be used where needed.

Knowledge developed by research is frequently not being used. More effort should be made to carry research results through the pilot test phase, to mobilize existing information for the development of predictive models, and to organize and synthesize fragmented information into practical guides for management decisionmaking.

A greater proportion of the wildlife research should be directed toward nongame species, particularly those threatened with extinction. The R. & D. support for all other outdoor recreation resources is far below that justified by their economic and social importance, and the need for better knowledge of how to conserve, manage, and use them most effectively.

Urban environmental problems are receiving far too little attention. All aspects of urban planning and development that relate to quality of living need increased emphasis. The avoidance of past mistakes and satisfying environmental needs in urban and suburban expansion should be of special concern.

Recommendations applicable to protecting and enhancing the environment are:

- More systematic, long-range planning, including better establishment of program priorities, is needed.
- Better mechanisms for insuring coordination and cooperation among agencies should be developed.
- Research information and technology should be more promptly and effectively field tested and put into operational use.

The following research needs are most critical:

- A greatly expanded program for protection and enhancement of recreation resources.
- More attention to nongame birds and animals, especially endangered species.
- Expansion of urban environmental studies.

Alternatives to the Use of Pesticides

The R. & D. trend today is toward greater emphasis on biological and other nonchemical methods of control rather than the use of pesticides. More than one-half of the research by USDA on pests is now directed toward nonchemical control. Despite this emphasis, the use of pesticides must be continued until alternate methods of control are available. The detrimental environmental impact of not using pesticides could be greater than that arising from their continued use. Integrated pest control methods used in concert should be given more impetus. This will require interdisciplinary teams in a systems approach.

Recommendations applicable to alternate methods of pest control are listed below:

- Intensity effort on systems approach to pest management, including modeling and integrated pest control.
- Increase research on fundamental biology of pest species.
- Improve remote sensing capability for defining pest problems.
- Assure continued R. & D. at present level to permit gradual replacement of persistent compounds with those of less persistence.

Noise

The principal R. & D. effort on noise pollution is directed toward controlling aircraft noise at the

source. A lesser effort is devoted to noise generated by ground-based transportation systems, high-speed equipment of various kinds, and to noise arising from natural causes.

Noise levels can be reduced but not eliminated. Continuing research is needed, however, on the response of man and other organisms to infrasonics and ultrasonics. Problems may arise because of more subtle effects from continued or repeated noise emissions. The effect of sonic booms on structures, humans, domesticated animals, and wildlife are being studied.

Expanded area-wide studies are needed to consider the causes, trends, and impact of transportation noise on people and communities. Such studies, utilizing appropriate models, would permit conclusions on acceptable noise levels, and on the effects of noise suppression methods, such as vegetation screens, and would provide more useful analytic tools for urban planners, vehicle manufacturers, and roadway builders.

Recommendations applicable to noise are:

- Expand research to determine the nature and degree of hearing damage resulting from continuous or repeated exposure to noise.
- Increase research with models on noise problems in transportation systems.
- Conduct area-wide studies to determine the impact of noise on people and on communities.

Radiation

Radiation R. & D. for this study was viewed as encompassing these activities that will lead to better protection of man and his environment from adverse exposure to both ionizing and nonionizing radiation. The major effort has been concerned with the evaluation of radiation effects on man, with particular emphasis on expanding the level of knowledge of both immediate and long-term results of exposure. This level of activity is justified and should continue. More R. & D. on prevention and control technology to avoid radioactive contamination is needed.

Current programs point out necessary studies for future nuclear power plants. Prediction has been reliable but is increasingly refined as research proceeds. More research to better understand, describe, and predict the pathways to man of radionuclides in terrestrial, fresh water, and marine environments is needed. Generally the effects of radiation on man are well known when compared with other pollutants.

There is an increasing need to evaluate the effectiveness of treatment systems for radioactive wastes. Land disposal methods offer promise as needed alternatives to ocean disposal, but they must be carefully developed and tested.

Recommendations applicable to radiation are:

- Accelerate development of procedures for—
  - Evaluating proposed power reactors.
  - Assessing their environmental impacts.
- Increase research on transport and fate of radionuclides in ecosystems.
- Develop and evaluate radioactive waste treatment and disposal systems.
- Expand program on prevention and control of radioactive contamination.
- Increase research to determine the hazard potential of human exposure to current and projected levels of nonionizing radiation, such as radar, microwaves, UHF radiation, and VHF radiation.

Population

Population impinges on the many factors affecting the quality of the environment. While reliable population data are essential to comprehending and coping with many environmental problems, we must avoid the gross oversimplification that equates "environmental control" with "population control."

The Commission on Population Growth and the American Future in its March 1972 final report undoubtedly will include a number of general and specific recommendations for research needed on population-environmental quality interrelationships. Because the Commission will have studied the problem in great detail, and this study was a cursory analysis, no recommendations are made in the population report. Thus far, there has been only minor Federal support of research on the population-environment interface. However, large-scale Federal investments undoubtedly will be required and warranted to investigate systematically the complex interaction of economic, technological, demographic, and other social factors that alone and in combination affect environmental quality. The interrelations among population, technology, and industrial development are in particular need of clarification.

Air Quality

SUMMARY

The chapter on air quality reports four major research categories: evaluation of effects, measuring and monitoring, prevention and control, and transport and fate.

This report includes most air quality research, development, and demonstration programs conducted by Federal agencies during fiscal years 1969–71. Research related to the role of noise and radiation in air quality appears in separate subchapters under special studies and in appendixes 7 and 8.

The research programs represent an investment of $62.51, $79.06, and $93.92 million by the Federal Government for fiscal years 1969, 1970, and 1971, respectively. The breakdown of these funds by agency is given in table 3 (p. 19) and summarized in figure 3 (p. 18). Two-thirds of the funds have been allocated to the development of prevention and control technology for stationary and mobile sources of air pollution. Major emphasis has been placed on the control of sulfur oxides and particulates from stationary sources and on the prevention and control on motor vehicle and aircraft emissions.

Evaluation of Effects

Research on the evaluation of effects of air pollution includes programs to develop and advance understanding of the nature, duration, and importance of effects of air pollutants, singly and in combination, on man, plants, animals, and nonliving objects. Both acute and chronic effects studies have been reported. Approximately 14 percent of the funds have been allocated to effects research.

Major research programs include projects to determine effects of air pollution on human health, livestock, vegetation, the food chain, and selected natural ecosystems. Recent studies have emphasized the effects of SO_x, CO_2, CO, particulates, NO_x, oxidants, hydrocarbons, and trace metals, singly and in combination. Research has included studies of the effects of aircraft and motor vehicle emissions of man and biota.

Measuring and Monitoring

Research classified as related to measuring and monitoring includes projects conducted to provide new or improved methods for identifying specific air pollutants and measuring their concentrations in the air. Approximately 15 percent of the funds have been allocated to research in this category.

Prevention and Control

Research related to the prevention and control of air pollution includes studies to discover, develop, test, and demonstrate methods and processes that will prevent or assist in managing air pollution problems and methods to restore local environments that may have been harmed by air pollution. Research in this category amounts to $38.27, $49.78, $60.48 million for fiscal years 1969, 1970, and 1971, respectively.

Research on prevention and control technology for stationary sources includes the development and demonstration of techniques for controlling particulates, sulfur oxides, and nitrogen oxides from electric powerplants and other combustion-related stationary sources. Major R. & D. programs aim to control sulfur oxides, for example, by dry limestone injection, limestone wet scrubbing, ammonia injection, and SO_x absorption by copper oxide impregnated into an alumina support.

Extensive mobile source control programs have been reported. Research is underway to modify both aircraft and passenger vehicle engines. For example, projects are being conducted to establish high efficiency removal devices for particulates; to verify carburetor design requirements for reduced emissions; and to determine the best materials for constructing a thermal reactor for hydrocarbon and CO removal. Work is currently being expanded to im-

FIGURE 3.—FEDERAL R&D FUNDS

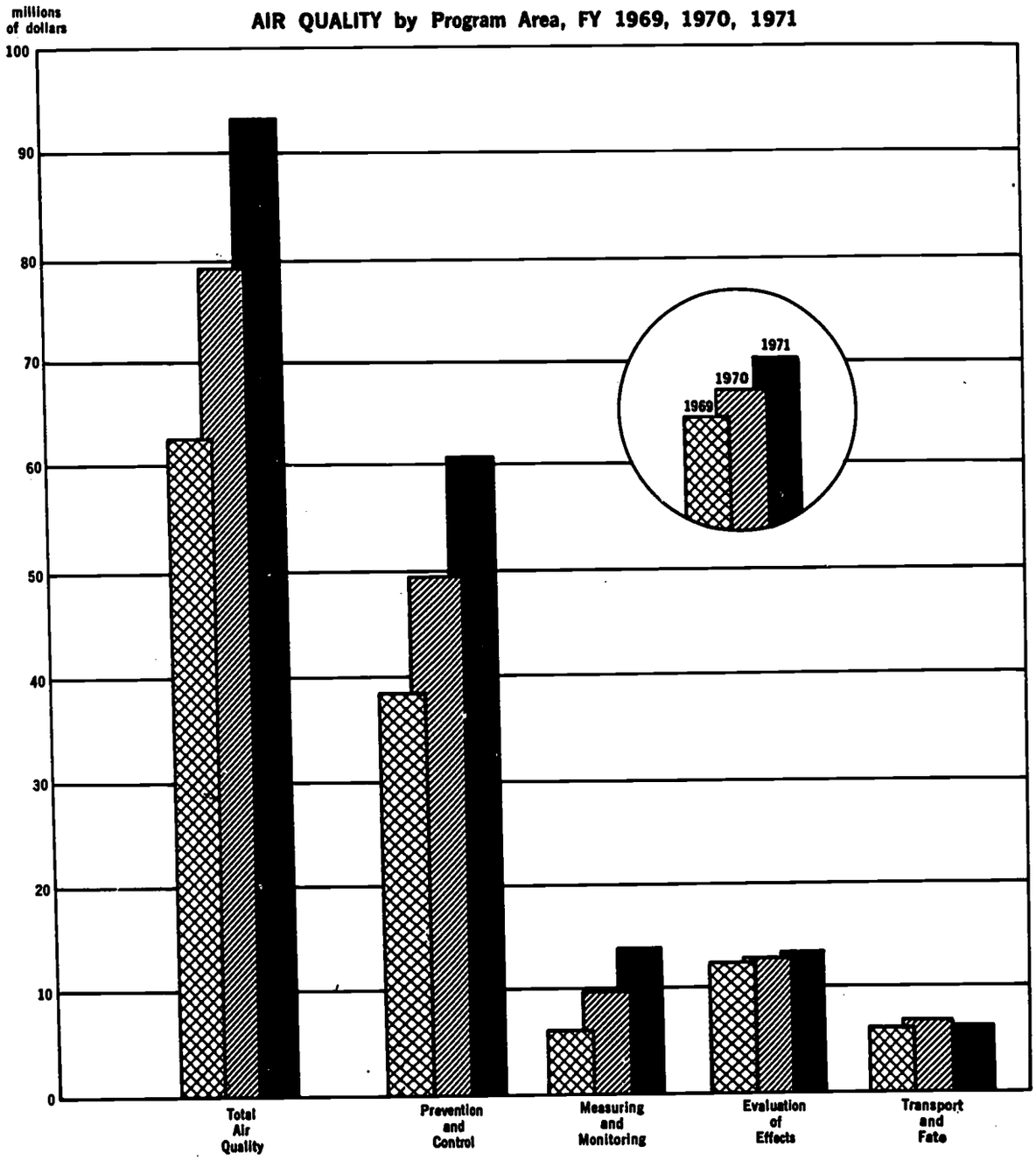


TABLE 3.—*Summary of funding for air quality research and development by various Federal agencies, fiscal years 1969–71*

[Figures in millions of dollars]

Agency nnd fiscal yenr	Evalu-ation of effects	Measuring and monitoring	Preven-tion and control	Trnns-port nnd fnte	Totnl
CE:					
1969	.....	.....	1.31	.....	1.31
1970	.....	.....	.25	.....	.25
1971	.....	.....	.04	.....	.04
USDA:					
1969	1.31	.....	2.59	.....	3.90
1970	1.36	.....	3.07	.....	4.43
1971	1.44	.....	3.25	.....	4.69
DOC:					
1969	.....	1.65	.....	.....	1.65
1970	.....	1.74	.....	.....	1.74
1971	.....	1.84	.....	.....	1.84
DOD:					
1969	.....	.02	8.24	.....	8.26
1970	.....	.03	7.30	.....	7.33
1971	.....	.09	7.43	.....	7.52
HEW:					
1969	.20	.....	.....	.....	.20
1970	.34	.....	.....	.....	.34
1971	.23	.....	.....	.....	.23
DOI:					
1969	.....	.40	4.98	.....	5.38
1970	.....	.80	5.58	.....	6.38
1971	.....	1.40	7.88	.....	9.28
DOT:					
1969	0	0	2.60	0	2.60
1970	.05	.15	6.23	.05	6.48
1971	.24	.33	3.89	.35	4.81
EPA:					
1969	8.60	2.80	17.77	4.80	33.97
1970	8.70	5.60	26.48	4.70	45.48
1971	8.45	7.74	34.26	4.20	54.65
GSA:					
1969	.....	.....	0	.....	0
1970	.....	.....	.11	.....	.11
1971	.....	.....	2.08	.....	2.08
NASA:					
1969	.....	.20	.15	.10	.45
1970	.....	.17	.27	.12	.56
1971	.....	.62	.92	.16	1.70
NSF:					
1969	2.24	.84	.45	1.06	4.59
1970	2.40	1.38	.32	1.67	5.77
1971	2.71	1.86	.56	1.76	6.89
TVA:					
1969	.02	.....	.18	.....	.20
1970	.02	.....	.17	.....	.19
1971	.02	.....	.17	.....	.19
Total all agencies:					
1969	12.37	5.91	38.27	5.96	62.51
1970	12.87	9.87	49.78	6.54	79.06
1971	13.09	13.88	60.48	6.47	93.92

prove the safety of diesel engines operating in underground mines. Steam and other low-polluting vehicles are being developed for transit buses.

A comprehensive advanced automotive power systems program is also in progress. It is designed to stimulate the automobile industry to independently develop the most promising candidate systems for low-pollution motor vehicles while the Government continues a Federal R. & D. program through to the demonstration of selected systems. Leading candidates are the gas turbine engine, the Rankine cycle engine, the stratified charge engine, and the small diesel engine.

Other research that would result in the prevention of air pollution is in progress. Fuel cells and high energy density batteries are being developed. Research to improve the design of coal-cleaning plants for removing pyritic sulfur has been reported. Coal is being treated to remove pyritics and other sulfur-bearing consituents by selective grinding. Investigations of the availability of low-sulfur fuels are also underway. New processes for removing sulfur from ores of copper and other metals are being developed. Improved processes for coal gasification and liquefaction are also being vigorously pursued. Magnetohydrodynamics combustion tests are being conducted. Various incinerator designs are being investigated, including high temperature, vortex, fluidized bed, and pyrolysis units.

Extensive research to prevent and control air pollution related to agriculture has also been reported. The relationship of soil erosion to air pollution is being studied. Research is in progress to prevent air pollution by pesticides and by smoke from burning crop and forest residues. Studies have been reported to identify the gaseous components from animal wastes that cause odor and to develop practices that reduce odor from these sources. Methods for protecting and maintaining adequate shelterbelts to reduce air pollution by soil particles are being developed. Also, to reduce the odors from pulping wastes, increased uses of these wastes, and improved pulping methods are being sought.

Transport and Fate

Research related to the transport and fate of air pollutants includes studies of the physical, chemical, and biological processes involved in the initial distribution, redistribution, cycling, and ultimate fate of air pollutants in the environment, including the processes by which contaminants are naturally degraded. Approximately 7 percent of the funds have been allocated to research related to the transport and fate of air pollutants.

Studies include mathematical systems analyses of air pollution problems using various diffusion models. Field and laboratory projects to evaluate the photochemical reactivity of pollutants also have been reported. Aircraft engine emission dissipation rates are

being determined. Investigations of the kineties of smoke and nitric oxides formation under conditions found in aircraft gas turbine combustion systems are being conducted. A study to analyse the amount and fate of persistent pesticides carried by air currents from the area of application is also underway.

Field measurements for input to models of the effects of heat from large sources such as cities are underway. Possible effects include changes in thunderstorm rain and changes in the diffusion and deposition of air pollutants.

Efforts to extend the distance and time ranges of transport models and to include the effects of changing rural to urban terrain on diffusion are underway. These are necessary to assess the effects of exposures of cities, regions, and continents to small quantities of radioactivity.

ANALYSIS

It is recognized that the Federal programs, while extensive, do not constitute the total national effort in air quality research. Many private concerns and State and local governments are also expending considerable resources in this area. Similar work is being conducted in other countries. To place some definite boundary on the discussion, however, this report includes only federally sponsored research, and various Federal programs may not be included for lack of data.

Major Trend in Research Related to Air Quality

Analysis of the research indicates that the major trend is toward allocating greater amount of Federal resources to the development of prevention and control technology. Two-thirds of the funds reported to the Committee in the area of air quality were related to prevention and control. This trend results in part from the emphasis placed on such research in the current Federal legislation. Also, various review groups, including the Council on Environmental Quality, have recommended that the Federal efforts in this area be increased.

Trends in Intramural vs. Extramural Research in Air Quality

The largest Federal program in air pollution R. &. D. is supported by the EPA, particularly through its Office of Air Programs. R. &. D. accounts for about half of EPA air pollution control funding. This research is supported in-house, by interagency fund transfer, by grants to universities, and by contract. Analysis of the proportioning of EPA air pollution R. & D. funds indicates that although funds in all areas have risen since 1967, the percentage allocated to in-house work and university grants has proportionately decreased. Interagency fund transfers have increased gradually from about 10 percent to somewhat over 15 percent in fiscal year 1971. Contract funding has risen to a little over 50 percent of the total effort in fiscal year 1971. EPA uses the contract mechanism particularly in developmental areas such as full-scale demonstration projects; for example, processes for sulfur control in utility boilers, whose locale must be at the site of the powerplant. This has perhaps an added advantage in promoting air-pollution control research in the private industrial sector.

The other agencies conducting R. & D. in the air pollution area have reported that funding is also accomplished by various mechanisms. Much of the research supported by NASA, for example, is conducted in-house. NSF supports a variety of interdisciplinary and basic research efforts related to air pollution principally through the research grant mechanism. USDA through formula fund and special grants to State agricultural experiment stations and schools of forestry, also conducts various extramural research in addition to the work done in-house. DOI supports an extensive in-house program of research related to air pollution control associated with mineral resources utilization, mainly in the regional laboratories of the Department. This effort has been a continuing one and is now proceeding at an accelerated pace. DOT supports in-house and contract research directed toward reducing air pollution from transportation systems and vehicles.

Relative Priority of Air Quality R. & D. Problems and Requirements

On February 10, 1970, President Nixon sent to the Congress an historic message on the environment. In part he said, "I am inaugurating a program to marshal both government and private research with the goal of providing an unconventionally powered virtually pollution-free automobile with 5 years." In this way the President chose to recognize the principal urban air pollution problem of the Nation: The automobile. The Congress, in part responding to the President's message, enacted the 1970 amend-

ments to the Clear Air Act and actually made the development of such a vehicle by 1975 a legal requirement.

When the various data reported are reviewed, it is clear that the various Federal agencies with expertise in mobile source pollution control have responded to the President's mandate in an almost unprecedented manner. The largest program in mobile source pollution control is conducted by EPA. Of particular interest is that EPA, through interagency transfer, is supporting programs in this area in DOI and in NASA. All Federal agencies are not concentrating on the automobile per se, but the technology developed by DOT and DOD, for example, for measuring and controlling emissions from mobile sources such as aircraft should be of use in controlling or measuring emissions from other mobile sources. In sum, the Federal involvement in mobile source pollution control represents a multimillion dollar investment, and a high priority obviously has been assigned to these programs by the various agencies.

Another problem area that is being funded in multimillion dollar amounts relates to controlling emissions from stationary sources of air pollution such as electric powerplants. Emissions from fossil fueled plants are being investigated by DOD, DOI, EPA, and TVA.

DOI and EPA are also conducting an extensive program to prevent or reduce air pollution from combustion-related stationary sources. Improved processes for coal gasification and liquefaction are being pursued. Magnetohydrodynamics combustion tests are being conducted.

Significant research on stationary sources is also being conducted by EPA's Office of Solid Waste Management Programs, DOD (both military and civil works), NSF, and DOI's Bureau of Mines, relating particularly to the control of emissions resulting from the incineration of solid wastes.

USDA has reported various investigations related to controlling agriculturally related air pollution. For example, projects are underway to determine the relationship of wind erosion of soils to air pollution and concomitantly to reduce damaging effects of airborne soil particles on seedlings and crop plants. Other research is concerned with reducing smoke and odors from agricultural operations.

Methods to evaluate and prevent air pollution by pesticides are being developed by USDA. NSF is determining the amount and fate of DDT carried by wind from the area of application of the chemical. AEC is also conducting an extensive R. & D. program aimed at understanding the transport and fate of radioactive substances released to the air from nuclear facilities.

The various agencies have also assigned priority to the development of measurement and monitoring methods for various air contaminants. Although EPA has invested the greatest dollar amount of all agencies reporting work in this area, almost every Federal agency reporting to this Committee is investigating some facet of this problem.

As noted above, the significant trend in air quality R. & D. is that the highest percentage of research funds reported is being spent on the development of prevention and control methods. Effects research, however, is still being emphasized, particularly in EPA, USDA, and HEW. For example, since exposure to atmospheric pollutants is considered to be an important contributor to the total lung cancer hazard of the population, there has been an increasing effort in this area by HEW's National Cancer Institute. Among the air pollutants studied under this program are the polycyclic hydrocarbons and related heterocyclic compounds, tobacco smoke, and a variety of airborne dusts such as asbestos and metal oxides. Additional research that will contribute to greater understanding of the effects of air pollution, but is not conducted for that purpose, is included elsewhere in this report.

Integrating and Team Efforts Necessary

Research efforts in the various air quality programs are directly coordinated within the various Federal agencies, principally through such mechanisms as interagency fund transfers. Although parallel efforts exist, they are not necessarily detrimental to the total Federal effort, provided they are recognized by the agencies funding the research.

A project planned for St. Louis, Mo., represents an example of a team approach to the solution of air quality R. & D. problems by various Federal agencies. Although plans for the project have not been finalized, NOAA, EPA, NSF, AEC, and a diversified group of national laboratories, universities, and State agencies may participate in this project to study the air pollution problem of a single metropolitan area and all its ramifications—chemical, meteorological, and biological.

Other examples of interagency team approaches to the solution of air quality problems include a project undertaken by AEC, NSF, and NOAA. Scientists from the three agencies have recently increased the utilization of the AEC aircraft and balloon sampling

system to gain knowledge of present amounts of ozone, water, and pollutants expected from supersonic transport (SST) operations. The high altitude system exists due to a continuing AEC–DOD cooperative effort on radioactivity monitoring for stratospheric circulation research.

Integrating and team approaches are particularly important when dealing with the private sector. DOD, DOT, and NASA, for example, have established a well-recognized program in cooperation with the private sector in sponsoring defense and aerospace research.

In the air quality area, DOT works closely with aviation system developers to insure that environmental considerations enter into the design of major projects. USDA has established an extensive cooperative research program with the various State agricultural and forest conservation programs. NSF, which conducts most of its research related to air pollution through the grants mechanism, has also established a history of cooperative and integrating efforts with private, not-for-profit organizations.

Integration efforts are also necessary between EPA and private industry to develop a low-polluting advanced automotive power system as an alternative to the conventional engine in the event that the latter fails to meet the 1975–76 statutory emission standards.

EPA, through its Office of Air Programs, is also presently involved in cost-sharing (50–50) demonstration and pilot plant projects with other Government agencies and private industry to remove sulfur oxides and particulates. The demonstration projects include (1) dry limestone injection (TVA), (2) wet limestone scrubbing (TVA-Key West-Zurn), (3) catalytic oxidation (Monsanto), and (4) magnesium oxide scrubbing (Chemico). The pilot plant projects are (1) modified chamber process (Tyco), (2) char process (Westvaco), and (3) ammonia scrubbing (TVA).

In addition, research under the direction of the Coordinating Research Council Air Pollution Research Advisory Committee is sponsored by the American Petroleum Institute, the Automobile Manufacturers Association, and EPA on a cost-sharing basis. The four main areas of activity are engineering projects, atmospheric projects, medical projects, and in-house programs. The EPA program is unique among Federal environmental research programs.

Discussion of needed integrating efforts in air quality R. & D. would be incomplete without mention of the importance of industrial hygiene research findings to air quality programs. In many cases, the first indication of the hazardous nature of a particular contaminant occurs in the occupational environment. Measurement instruments developed for the use of occupational health and safety personnel often can be utilized for air pollution control work.

The agencies reporting air quality R. & D. have indicated that they recognize the importance of coordinating air quality and occupational health research programs. DOI's work in air quality R. & D., for example, is conducted for the most part by the Bureau of Mines, where significant mine safety research has been underway for many years. The DOD also conducts a variety of industrial hygiene and medical research projects on the toxicology of various substances, much of which is directly relevant to air quality problems.

Modeling and Systems Approach

A number of agencies are conducting research involving mathematical modeling of air quality problems. Modeling designed to predict air pollutant concentrations likely to occur as a result of various meteorological conditions, emission rates, and patterns is generally based on a diffusion model that mathematically simulates the transport of pollutants through the atmosphere. Though a single diffusion model may be applicable in more than one community, no single model is suitable for all sets of circumstances. Different types of models also are required to predict short-term and long-term pollutant concentrations.

The AEC, for example, has developed a model for predicting radiation dose to man from a future nuclear industry over an entire region by air, water, and a variety of food pathways. One type of model has already been applied by the AEC to the upper Mississippi basin, and another approach is under development using the Chesapeake Bay and its feed rivers in demonstration. Among other parameters, the models consider the living habits, diets, age, and sex of the individuals; the industries and food crops of the area; the meteorology of dry and wet deposition of pollutants; and the artificial and natural radioactivity entering and leaving the system.

To construct improved, realistic models, sensing devices of high accuracy, both remote and otherwise, will be needed. Additional research also should be pursued to determine modeling parameters such as vertical profiles of wind and temperature, turbulence, plume geometry, and pollutant concentrations. High priority should be given to photochemical modeling

to better understand the diverse phenomena involved in photochemical smog. Results of research in this area are being applied to practical air pollution problems through the NATO Committee on the Challenges to the Modern Society in Ankara, Turkey, and Frankfurt, Germany. Also, some modeling systems and field test results currently in existence may be applicable to modeling and predicting the movement of pollutants.

The need for a systems approach to solving environmental problems has been stated over and over again by various professional review groups. The various pollution control programs of the Federal Government must be integrated to facilitate the application of various operations research techniques to the solution of not only air quality problems but to understanding the interrelationships of air, water, and land pollution, including consideration of the various kinds of chemical and physical pollutants.

Where Should R. & D. Attention be Focused in the Future?

Rather than attempt a comprehensive listing of gaps existing in the Federal R. & D. effort, one or two areas that should receive increased attention are discussed here.

Whether one chooses to analyze Federal air quality research in terms of prevention and control, transport and fate, measuring and monitoring, or effects, it seems that greater priority should be assigned to research programs aimed specifically at understanding the action of various pollutants in combination and the resultant effect on man and his environment.

A primary goal of air pollution control, for example, is to obtain an in-depth understanding of chemical transformations and the distribution and fate of pollutants from the time they are emitted from a source to the time they are removed from the atmosphere by a sink. Greater attention should be focused on this subject in the future.

Programs to develop prevention and control technology for mixtures of various air pollutants should also be expanded. It is well recognized, for example, that the presence of lead in gasoline destroys the utility of catalytic control methods. Similarly the presence of certain plastics in municipal wastes can affect the operation of incinerator effluent control devices. Although these specific problems are being investigated by the agencies, many other problems of this nature likely exist.

Synergistic or other interactive effects of combinations of air pollutants should be given priority attention. Major attention has been focused on the combined health effects of SO_x, and particulates, for example, but additional research of this nature should be vigorously pursued. Until the air pollution problem is abated by adequate control at the sources, additional R. & D. to provide the necessary scientific and technical basis to adequately protect health and welfare must be continued. Research on the health effects of various contaminants must continue to be stressed so that realistic evaluations of the adequacy of standards can be made.

Increased attention should be given to the potential for interactive effects on man, biota, and structures from a combination of physical, such as noise and radiation, and chemical pollutants. A comparatively small amount of research is being conducted in this area. EPA, for example, has supported research on the combined effects of certain pesticides and ionizing radiation. Also, synergistic effects of smoking and the inhalation of pollutants from diversified industrial activities have been studied. For example, epidemiologic studies of underground uranium miners have shown that a synergistic effect may result from the continued exposure of smokers to high radon daughter concentrations.

The development of measurement methods for combinations of chemical pollutants is receiving some attention. EPA, for example, is developing a single multichannel analyzer, which will analyze vehicle exhaust for carbon monoxide, carbon dioxide, hydrocarbons, and nitrogen oxides. NASA has reported similar work. However, accurate, low-cost, portable instruments for field use are urgently needed.

Although perhaps somewhat outside the scope of this Committee, it is believed that a more comprehensive and detailed program of research in basic and applied economics is urgently required since these considerations are an integral and important part of a rational national attack on our air pollution problems. For example, DOT is supporting a study of the probable social, economic, and technical impacts that might result if it becomes necessary to change from mass production of the internal combustion engine to mass production of nonconventional low-polluting power systems for motor vehicles.

New Legislation

The Clean Air Act Amendments of 1970 will significantly increase R. & D. activities throughout the Nation. Included will be research on the diverse health effects directly traceable to air pollutants;

preparation and publication of air quality criteria and associated control techniques documents; monitoring of air pollutants; development of more effective stationary source technology; and acceleration of mobile source pollution control technology (including aircraft).

CHAPTER 4

Water Quality

SUMMARY

The total Federal R. & D. effort in water quality in fiscal year 1971 is $115.37 million carried out by 12 Federal agencies with over 64 percent of the program being administered by EPA. The water quality program is presented on the basis of pollution sources, that is, agricultural, industrial, mining, municipal, and other sources, with special reference to control technology. The programs are also presented on the basis of salinity research, thermal research, waste treatment and ultimate disposal, water quality, and water quality requirements research.

Figure 4 (p. 26) and table 4 (p. 27) summarize the funding of each of these categories by each of the Federal agencies involved in water quality R. & D.

Agricultural Water Quality Control Technology

This R. & D. program involves development and demonstration of technology for effective and economic control of water quality from agriculture, forestry and logging operation, irrigation return flow, rural runoff, and animal feedlots. Procedures are being developed to reduce runoff of fertilizers, pesticides, and dissolved organics that leach from plant residues and to completely eliminate pollution from animal feedlots through recycling of waste constituents. Research is being supported on increased beneficial use of crop and forest residues, including their use to prevent soil erosion. Research on liquid wastes from processing raw agricultural products is being undertaken to show effectiveness of land disposal or application by sprinkler or furrow irrigation to fertilize crops. Byproduct recovery and utilization and improved harvesting and processing are being studied. Mathematical models are being developed for predicting nutrient movement in soil and for studying processes of nutrient cycling.

Industrial Water Quality Control Technology

The objective is to develop economical technology for complete control of industrial waste discharges. New or improved systems for significantly reducing waste have been demonstrated for metal plating shops, steel mills, food processing plants, pulp and paper mills, organic chemical plants, and petroleum refineries. The program includes pretreatment techniques for safe discharge into municipal systems, closed-loop systems to eliminate industrial waste, and renovation and reuse of waste waters and byproduct recovery.

Mining and Related Water Quality Problems

This R. & D. program is being supported on elimination of water pollution caused by extraction and preparation of minerals, including coal, copper, other metals, oil, phosphate, rocks, sand, and gravel. A major effort is placed on treating coal mine acid discharges, including desalting processes to provide fresh water for municipal and industrial use; on developing new methods for sealing mines; and on evaluating new mining methods and techniques to reduce discharges.

Research is also conducted to find ways of modifying processes for converting animal, crop and timber products so that wastes are reduced. Development of technology for byproduct recovery is an important aspect of this experimental work.

Municipal Water Quality Control Technology

R. & D. involves improving or lowering the cost of treating and enhancing effluents from municipal sewage, storm sewer discharges, combined storm and sanitary overflows, nonsewered runoff, and joint municipal/industrial wastes. Major emphasis will be on using existing technology for sewage treatment and for development of technology for removal of phosphorus, bacteria, viruses, nutrients, and refractory organic wastes. The in-sewer treatment of sewage for individual and clusters of homes will continue, increasing efficiency of municipal systems, assigning constraints on industrial loads, and studying the impact of urban storm water discharges.

FIGURE 4.—FEDERAL R&D FUNDS

WATER QUALITY by Program Area, FY 1969, 1970, 1971

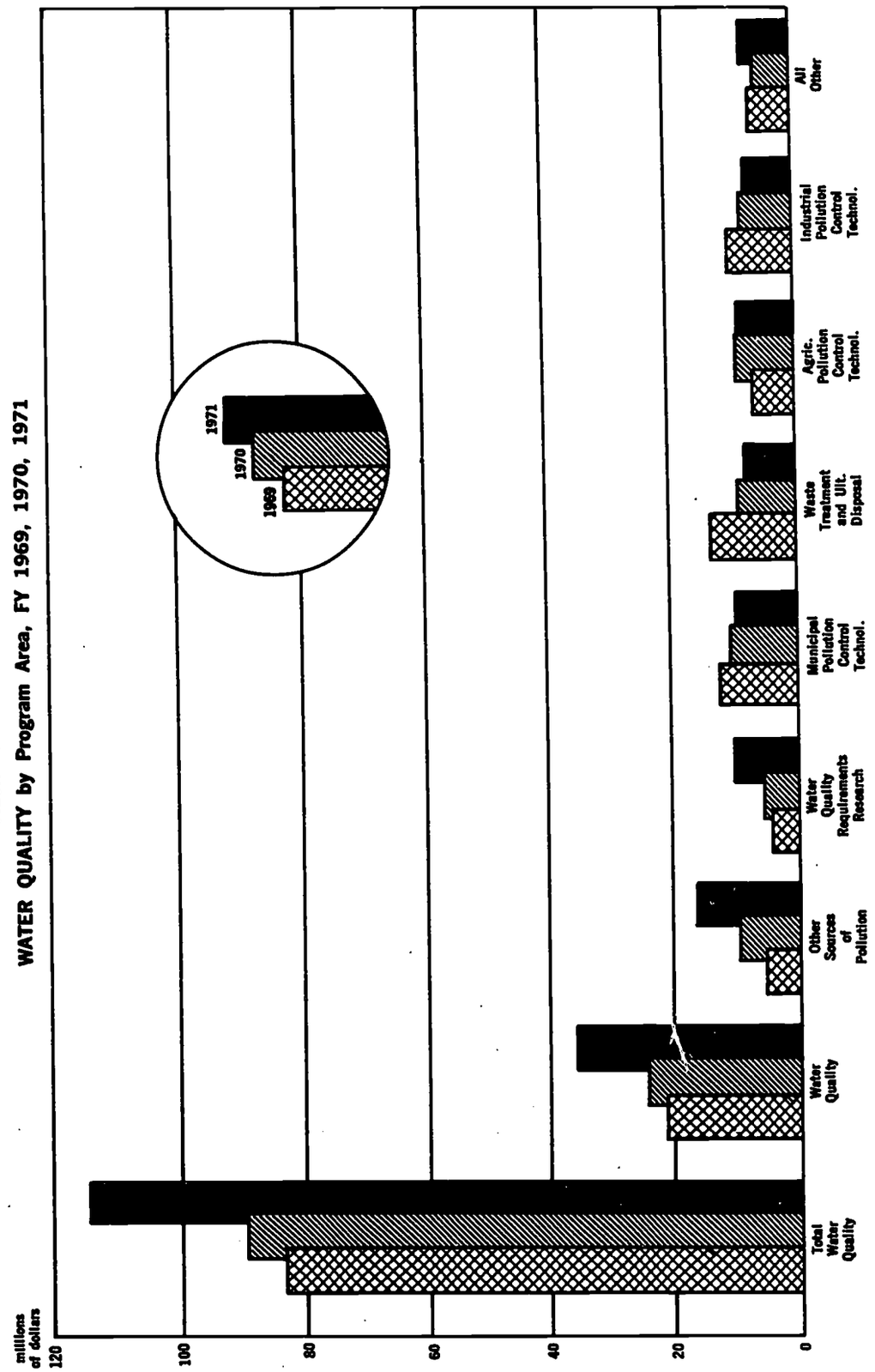


TABLE 4.—*Summary of funding for water quality research and development by various Federal agencies, fiscal years 1969–71*

[Figures in millions of dollars]

Agency and fiscal year	Agricultural pollution control technology	Industrial pollution control technology	Mining pollution	Municipal pollution	Other water quality problems	Salinity research	Thermal research	Waste treatment and ultimate disposal	General water quality research	Water quality requirement research	Total
AEC:											
1969					[1] (6.80)		0.85	[1] (3.31)			0.85
1970					(8.10)		1.49	(3.10)			1.49
1971					(9.29)		3.25	(3.44)			3.25
CE:											
1969					.09		.10		0.10		.38
1970					.18		.20		.14		.52
1971					.21		.21		.87		1.29
USDA:											
1969	5.22	1.27			2.12	1.35					9.96
1970	6.71	1.30			2.11	1.42					11.54
1971	6.02	1.73			2.18	1.51					12.04
DOC:											
1969					.09		[2] .27		.25		.61
1970					.18		.20		.25		.63
1971					.21		.15		.58		.94
DOD:											
1969					.07			.59			.66
1970					.07			.96			1.03
1971					.13			1.00			1.13
DOI:											
1969			0			1.60	.35	.09	9.46		11.50
1970			.04			1.70	.49	.11	9.25		11.59
1971			.06			1.87	.52	.13	10.59		13.17
DOT:											
1969					.41			.10	.29		.80
1970					3.61			.11	.55		4.27
1971					2.50			.30	1.20		4.00
EPA:											
1969	1.37	9.01	3.43	12.13	1.89		[2] .85	11.67	10.69	4.05	55.09
1970	2.44	7.36	2.71	10.45	2.77		1.75	7.26	13.47	5.49	53.70
1971	2.47	6.00	4.52	9.82	10.83		2.87	5.35	22.78	10.38	75.02
HUD:											
1969							.10				.10
1970							.10				.10
1971							.10				.10
NASA:											
1969								.70			.70
1970								.98			.98
1971								1.28			1.28
NSF:											
1969				.35	.86		.74				1.95
1970				.35	.75		.89				1.99
1971				.43	.82		.90				2.15
TVA:											
1969	.03						[2] .24		.44		.71
1970	.05						.42		.48		.95
1971	.05						.42		.53		1.00
Total all agencies:											
1969	6.62	10.28	3.43	12.48	5.53	2.95	3.59	13.15	21.23	4.05	83.31
1970	9.20	8.66	2.75	10.80	9.67	3.12	5.54	9.42	24.14	5.49	88.79
1971	9.14	7.73	4.58	10.25	16.88	3.38	8.42	8.06	36.55	10.38	115.37

[1] These AEC figures are not included in the totals, but are included in the radiation section of the special studies.
[2] Expenditures relating to thermal pollution obtained from OST report "The Effects and Control of Heated Water Discharges."

Other Water Quality Problems

R. & D. is conducted to develop and demonstrate technology for control of water quality related to recreational activities, watercraft, construction projects, impoundments, salt water intrusions, natural pollution, dredging and land fill, and spills and discharges of oil and hazardous materials, including

pesticides, herbicides, and heavy metals. Major effort by several agencies is on the problem of oil spills and clean up, including development of techniques for detecting, chemical treatment, spill control equipment, high-depth tanker design, floating barriers, sorbent, and other systems. Sediment control research and development involves sediment trap efficiency of improved reservoirs, sediment transport and deposition, erosion control, and the study of the carrier role for phosphorus and pesticides. Research is supported on biogeochemistry of heavy metals in fresh water and the ocean. Research is conducted on overgrowth of algae and aquatic plants and herbivores and herbicides for their control.

Salinity Research

R. & D. studies on desalting plants include development of intake structures and antifouling devices to minimize the amount of marine life present, the ecological effects of introducing large quantities of waste brine, and the synergistic effects of increased salinity and copper and high temperatures. Studies are supported to convert geothermal brines to desalted water, to recover useful byproducts, and to dispose of wastes safely. Solar ponds for evaporation and deep wells for ultimate disposal are being studied.

Dissolved salts in irrigation water present a serious problem, and methods are being studied and developed to better control salinity, minimize evapotranspiration, and control phreatophytes and seepage. Effects of salt tolerance are being studied in areas where salt water must be used. The problem of saline intrusion from the oceans into fresh water surface and ground systems and the land is also a serious problem.

Thermal Research

Research is conducted to study the causes and effects of thermal changes to streams, estuaries, and lakes especially those stemming from nuclear and fossil-fueled powerplants. Research includes studies of seasonal changes, urbanization, stratification, diffusion, mixing, evaporation, circulation, measurement techniques (including remote sensing), and the effects of increased temperature on the survival, growth, and reproduction of aquatic organisms and ecosystems. Mathematical and physical models are being developed to predict temperature distribution. Studies are underway on constructive use of waste heat for agriculture and aquaculture and on the increased value of such water for recreation, industry, and dwellings. The use of air diffuser systems and of submerged weirs is being investigated to determine effects on temperatures in stratified lakes.

Waste Treatment and Ultimate Disposal

Different methods of waste treatment and control are being studied, including development of methods to remove nitrogen, to handle sludges and brines, to renovate and reuse waste water, to remove and add to the water, to prevent and control scale, to remove iron and manganese, to control pH, to use for purification, to improve shipboard sewage control, to improve disinfection methods, and to develop procedures for tertiary treatment. Research is supported on irradiation of water, sewage treatment in cold regions and reclamation of photographic film wash water.

General Water Quality Research

Water quality research in this area covers a broad range of characterization and quantification of the determinants of water quality including sources, kinds, amounts, prevention, control, effects, reclamation, and fate of pollutants, mixing, sedimentation, erosion, and sorption studies, research on water cycles and hydrologic systems research. R. & D. programs include development and standardization of detection and identification methods, especially those for trace constituents such as heavy metals and biocides and transport and effects of the contaminants. Methods of monitoring, including development of remote sensing methods are being studied. Research on control of eutrophication by advanced waste treatment, nutrient removal, weed harvesting, and chemical inhibition is being studied. Demonstration of these methods is being attempted in several areas. Research in waste treatment is directed toward physical, chemical, and biological improvement of the quality of effluents and toward innovative methods to remove undesirable elements. Studies are supported on reaeration of waters to increase oxygen and prevent stratification, use of herbicides, and effects of high evaporation on salt levels. Mathematical and physical models are being developed to better understand complex systems and the transport and fate of water and pollutants in water bodies and watersheds.

Water Quality Requirements Research

This program provides the scientific basis for establishing improved water quality standards and for

predicting the water quality effects of the many new substances being constantly introduced into the water environment. Research involves all water uses, but especially the effects of pollutants on aquatic organisms. It is assumed that standards adequate to protect aquatic life will probably provide water quality suitable for other water uses. Research includes the establishment of water quality criteria for heavy metals, pesticides, hydrocarbons, petrochemicals, dissolved oxygen, complex industrial chemicals, and temperature.

ANALYSIS

The first annual report of the Council on Environmental Quality points out that institutional and management changes affecting our use of water play a role at least as important as scientific research in solving our national problems in this area. A major role for water pollution research, therefore, is to support water management by supplying tools for the development of a strong and coherent policy for achieving high water quality. These tools take two principal forms: (1) Developing a sound scientific base of information for making regulatory decisions and (2) developing systems and technology for solving specific water pollution problems.

A review of Federal water pollution control programs points out the complexity of the problems involved, the large number of Federal organizations that have activities in this field, and the significant number of differing research approaches that are being taken.

The level of effort of water quality research and development for 12 different Federal agencies was $83.31 million in fiscal year 1969, $88.79 million in fiscal year 1970, and $115.37 million in fiscal year 1971. In fiscal year 1971, about 42.5 percent of the program involved source pollution control technology, 31.5 percent multisource water quality control technology, and the remainder (26 percent) waste process technology, water quality requirements, and thermal and salinity research.

There appears to be a research and development trend toward widening a known research base, applying existing knowledge and technology to long-neglected problems, optimizing existing technology, reducing cost, and other management problems. The research focus is on providing input to the current surge of regulatory and control activity. This emphasis on current and short-term needs may result in temporary switches in research attention when attention is drawn to a toxic substance or pollution issue that catches the interest of the news media or the public. Environmental research is especially responsive to political pressures and public concern and care must be taken not to neglect long-term needs.

There are few broad areas of water quality research activity remaining that are not now the object of some research attention; the adequacy of this coverage varies a good deal. There is, for instance, insufficient research on levels of those substances that do not interfere with water uses. Further knowledge needs to be developed on the biological effects of temperature and temperature changes on various water systems, the role of sediment in streambank and channel erosion, and the magnitude and significance of dissolved and suspended material originating from plant and animal sources that enter water courses. New methods should be explored for disposing of saline drainage water to avoid degrading existing water resources. Processing methodology needs to be improved for greater emphasis on recycling or closed-loop systems. There is a definite need for greater involvement of new technology such as remote sensing in pollution surveillance and detection, including development of sensors for relevant pollution parameters.

There is agreement on the part of governmental organizations that the problem of ultimate disposal, such as deep wells or ocean dumping is receiving inadequate research attention and should be looked at from a broader environmental perspective. With the increasing use of nuclear plants and their associated relatively high thermal discharge, the problems of thermal pollution will undoubtedly continue to receive increasing attention. Translated into terms of actual projects, there will be a step-up in studies of the various technologic and economic options for cooling and the biologic effects of temperature change. Innovative research is needed in applying thermal effluents to beneficial uses, such as space heating, alleviation of ice conditions hindering shipping and extending the season for irrigation crops. Increased regulatory authority will require expanded research to develop water quality criteria for specific pollutants, such as heavy metals and synthetic organics, and for monitoring to establish reliable baseline information on water quality. Increasing pollution of the oceans will require further research on the effects of discharges from such activities as dumping of shore-generated wastes and exploitation of seabed resources.

Many actual or potential water quality problems, such as those resulting from detergent constituents, are not associated with point discharges and may require source control by restriction of manufacture or use. Such control would require research to develop criteria for defining what constitutes an environmentally hazardous substance and for screening materials for potential environmental effects. Current emphasis is on known problems. Increased attention is needed for a capability for predicting water quality issues. As waste treatment becomes more effective and reuse of renovated water more necessary, specific criteria will be needed to establish guidelines, especially in the public health area, for the uses to which such waters are put.

The Federal water quality programs were reviewed in light of comments by various groups. The recommendations for Federal water quality R. & D. from many private and government organizations, committees, and testimonies clearly request a greater and more imaginative program in certain areas than the Federal agencies are conducting. These recommendations not drawn from individual departments have been summarized as follows: Water should be protected from pollutants. Since water is reused, more knowledge is required on the effects of waste treatment processes on harmful substances and organisms and on the compositional amounts of wastes introduced by industry. An inventory of industrial wastes is recommended. New and innovative approaches should be made to supply treatment. More knowledge on effects of water treatment on heavy metals, viruses, and others is required.

There is genuine alarm concerning the inadequacy and poor results obtained by present archaic methods of waste treatment. This is based on concern that present primary and secondary methods do not remove nutrients, toxic heavy metals, and disease pathogens from the effluent, and they do produce large quantities of sludge that cause a severe pollution problem. New and innovative approaches are recommended, including recycling of waste with creative beneficial use of both effluent and solid sludge for fertilization and other uses but at the same time preventing water pollution.

Other recommendations include: Increased studies of effects of pollutants, including oil or organisms, especially in estuaries; increased studies on conservation and increase of water in semiarid regions; and improved knowledge and methods for handling oil pollution.

A very large proportion of Federal agency budgets deals with water quality related to construction of facilities and other activities using known technology. The proportion of funding devoted to research is relatively small, and increase in levels of support is sorely needed.[5] The cost of providing adequate municipal waste treatment is estimated at about $10 billion per year.

A Federal expenditure of $4 billion per year was recommended to match municipal expenditures. (End of recommendations from outside groups.)

While the increase and broadening of environmental concern may have led to some overlap of research activities, it is difficult to determine the degree to which such overlaps could represent unnecessary duplication. In the case of pesticides and oil pollution, for example, interagency groups exist that have coordination as one of their primary functions. From the program descriptions provided, however, there is a high probability that at least some research is undesirably duplicative. A project by project comparison would be needed to confirm this.

More intensive use of coordinated efforts and interdisciplinary team approaches and a clearer definition of the responsibilities of various agencies are necessary in water pollution. Although there are some obvious examples of meaningful specific cooperative programs, such as the EPA–DOI support of water research information transfer and interagency groups existing in fields such as oil pollution and pesticides, a review of program descriptions indicates greater need for interdisciplinary team approaches and more detailed coordination in certain critical areas of pollution. Oil pollution cleanup also appears to receive an unbalanced amount of attention from various government agencies.

Physical and mathematical modeling, and combinations of both, are being used to some extent. However, a strong case can be made for greater reliance on these techniques in studying the effects on ecosystems. These models are rapidly becoming more sophisticated and contribute to avoiding or lessening future water pollution problems. Systems analysis has similar potential in underlining the basic unity of the environmental structure. A greater reliance on the systems approach is especially needed where there is a promise of reclaiming waste water or recycling potential pollutants that now add to the load of undesirable inputs to our water. Because this type of analysis requires reliable data and information of water quality interactions, concurrent emphasis

[5] The agencies themselves did not report an imbalance between monies spent for construction of facilities and research. See last page of this chapter.

should be given to develop relevant data for input to models.

While there is general agreement that funds spent for water quality R. & D. should be greatly increased, there is no clear evidence, from the programs described in this report that the relative balances of support now going for R. & D. as opposed to construction of facilities should be significantly altered.

CHAPTER 5

Land Quality

SUMMARY

This chapter describes the R. & D. currently conducted by Federal agencies relating to land quality. The total effort represents both intramural and extramural R. & D.

Figure 5 (p. 33) and table 5 (p. 34) summarize the funding of each of these categories by each of the Federal agencies involved in land quality R. & D.

Historically, the quality of our land always has been an important concern. Before the present emphasis on environmental quality, concern centered primarily on erosion—the process of losing fertile topsoil to the ravages of wind and water. Within recent times, however, emphasis has shifted to pollution of land. Erosion is still a problem, but is now but one element of a much broader awareness that the land resource must be protected.

Pollutants contributing to the potential deterioration of land quality include pesticides that resist degradation, inorganic salts that accumulate and cause phytotoxicity, plant nutrients in the form of fertilizers that have secondary adverse effects on water quality, animal wastes, industrial processing wastes, heavy metals, crop and forest residues, and radioactive nuclides. Some of the pollutants have direct effects on land and its capacity for primary production. Others have secondary effects on the quality of surface or ground water, or on the quality of air. Solutions to problems relating to land quality can be solved only by a concerted effort on all aspects of the environment.

In tonnage, sediment arising from water and wind erosion is still the primary pollutant. Complete control of sediment will never be possible. It is possible, however, to reduce the amount of sediment by the maintenance of adequate vegetation on land and by the creation of wind barriers to reduce water and wind erosion. Effort in this area must not be permitted to decline as emphasis on other pollutants increases.

Persistent pesticides are a pollutant of land and also of water and air. Considerable R. & D. effort is underway on nonchemical methods of pest control. Nonchemical methods include biological, mechanical, and cultural control. Other methods, such as attractants, repellents, regulators of growth and development, and pheromones, are partly chemical and partly biological. Nonchemical methods of pest control offer much promise in the future. There is agreement, however, that chemical pesticides will continue to be necessary to insure adequate agricultural production and to protect human health. A systems approach to pest control holds the most promise for the future. Integrated use of chemical, biological, mechanical, and cultural control must be fostered in order to reduce the amount of chemicals being introduced into the environment.

Animal wastes are an increasing concern. To maintain economically competitive positions, producers have had to specialize, automate, and increase the size of their operations. This has resulted in greater concentration of livestock, and thus a greater concentration of wastes into a small area. Land is the only reasonable disposal site. A better understanding is required of the reaction of animal wastes in the soil. High concentrations of animal wastes may reduce the productive capacity of the land.

Recent restrictions on disposal of sewage sludge in water will result in increased disposal on land. Attendant problems parallel those of animal wastes. It is unreasonable to expect that animal and human wastes can be repeatedly applied to land without experiencing problems; for example, the accumulation of heavy metals. Land has a finite capacity to absorb and assimilate wastes. Accelerated research is critically needed to solve problems that will surely arise in the future.

Soil salinity will become a more serious problem as the acreage under irrigation increases. Acreage of land under cultivation has decreased in recent years. Irrigation is one of the factors involved in increased production per unit area.

Forest and crop residues pose some of the same

FIGURE 5.—FEDERAL R&D FUNDS

LAND QUALITY by Program Area, FY 1969, 1970, 1971

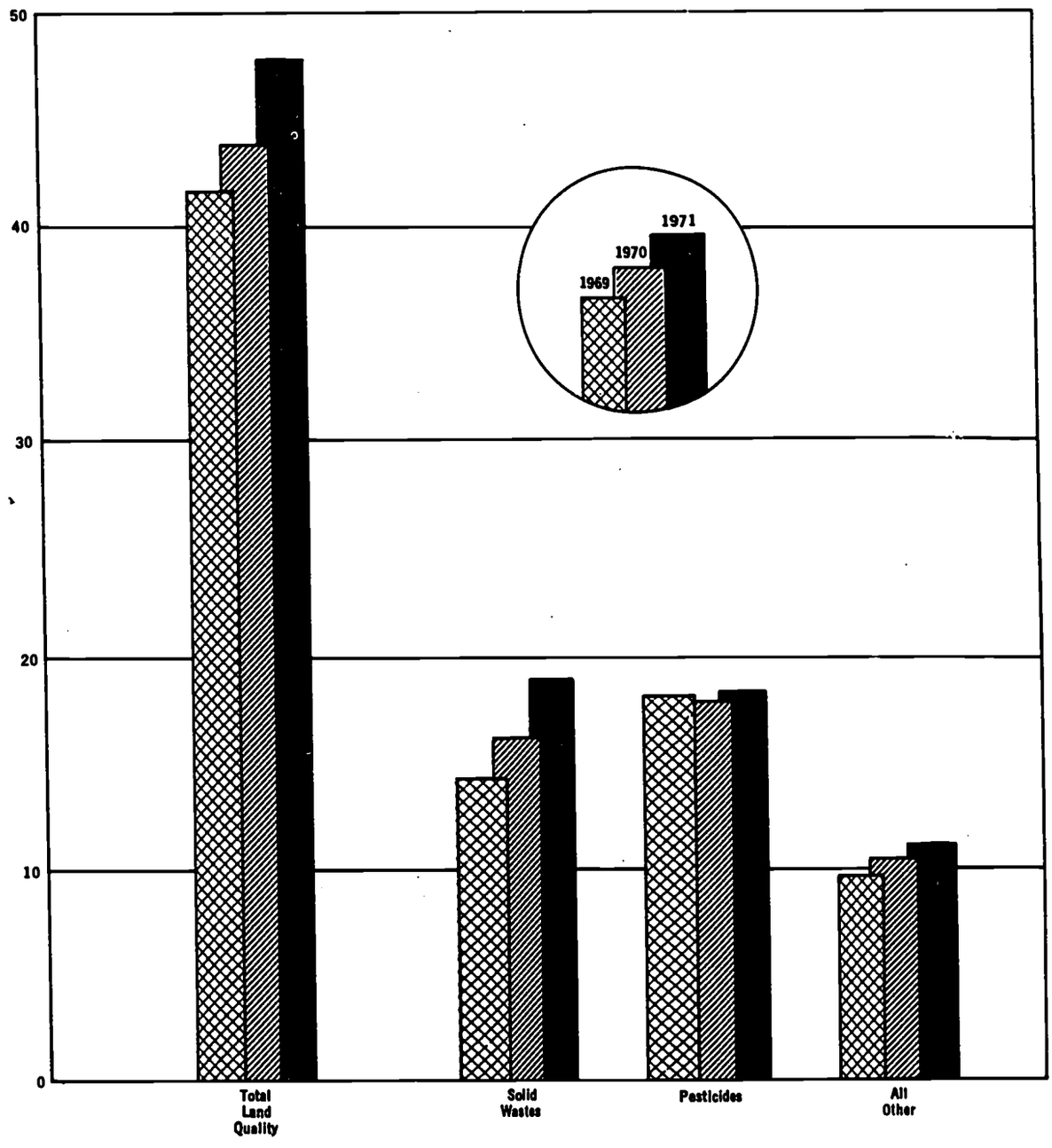


TABLE 5.—*Summary of land quality research and development for various Federal agencies, fiscal years 1969–71.*

[Figures in millions of dollars]

Agency and fiscal year	Animal wastes research	Forest and crop residues	Heavy metals	Industrial processing wastes	Pesticides research	Plant nutrients	Salinity research	Sediment research	Solid wastes	Other (unclassified) land quality research	Total
AEC:											
1969					0.05						0.05
1970					.03						.03
1971					.03						.03
CE:											
1969								0.10			.10
1970								.12			.12
1971				0.03				.13			.16
USDA:											
1969	0.49	2.36	0.06	.19	8.68	2.33	0.76	3.03	1.42	1.32	20.84
1970	.60	2.51	.06	.21	8.69	2.38	.80	3.15	1.65	1.32	21.37
1971	.92	2.88	.06	.22	9.81	2.60	.85	3.37	2.20	1.50	24.41
DOC:											
1969									.10		.10
1970									.20		.20
1971									.20		.20
DOD:											
1969											
1970									.10		.10
1971									.20		.20
DOI:											
1969					2.40				4.40		6.80
1970					2.40				4.90		7.30
1971					2.60				4.59		7.19
DOT:											
1969									.01		.01
1970									.01		.01
1971									.01		.01
EPA:											
1969									8.19		8.19
1970									8.99		8.99
1971									11.40		11.40
HEW:											
1969					6.10						6.10
1970					5.30						5.30
1971					5.60						5.60
NSF:											
1969			.10						.10	.60	.80
1970			.10						.30	.59	.99
1971			.50						.45	.09	1.04
TVA:											
1969				.20							.20
1970				.30							.30
1971				.10							.10
Total all agencies:											
1969	.49	2.36	.16	.39	17.23	2.33	.76	3.13	14.22	1.92	42.99
1970	.60	2.51	.16	.51	16.42	2.38	.80	3.27	16.15	1.91	44.71
1971	.92	2.88	.56	.35	18.04	2.60	.85	3.50	19.05	2.19	50.94

problems caused by human and animal wastes. Information is now inadequate to understand the biophysical and biochemical relationships that occur during residue decomposition.

Radioactive substances in the land result from fallout after nuclear explosion, from power reactors for power or propulsion, and from other sources of manmade radioactivity. Considerable research is being conducted on the fate and effect of radionuclides in terrestrial systems on such biological processes as behavior, food production, succession, migration, and reproduction. Studies are continuing to determine more precisely the effects of radiation on biological populations including man.

Mineral and organic junk and urban refuse are a blight on the landscape. Studies are underway to improve the technology for sanitary landfills and to improve the opportunities for recycling.

Refuse from mining and milling operations and denuded land resulting from strip mining contribute to the deterioration of land quality. R. & D. in this field involves the recovery of valuable materials from mining and milling operations and the revegetation of strip-mining sites to improve esthetic quality, to provide habitats for wildlife, and to provide additional areas for recreational use.

With increasing pressure on land for the disposal of various wastes, problems will become more severe. R. & D. efforts in the future must be geared to solutions of problems before they become severe. Thus, it is critically important that a national land policy be developed in terms of local, regional, and national planning. Only through such a concentrated effort can the quality of our land be maintained.

ANALYSIS

The pervasive public concern about environmental quality extended to the land after initially expressed concern regarding the deterioration of air and water quality. Today there are standards governing air and water quality, but no standards have been developed for land. Historically, water has been the preferred sink for the disposal of wastes. Increasing restrictions on pollution of water mean that increasingly more attention will be given to land for the disposal of wastes. Land has a finite capacity to absorb and assimilate wastes. Thus, it is important to establish guidelines and develop standards soon, so that the insult of pollution to the land can be kept to a minimum. For example, sewage sludge and urban refuse contain heavy metals. Repeated applications to land may result in heavy metal accumulation to the point of phytotoxicity.

The potential for increasing deterioration of land quality was well recognized by President Nixon in his February 8, 1971 message to the Congress on environment. In that message he urged the development of a National Land Use Policy. Such a policy is vital for wise land use in the future. Particularly important is a policy for regional planning. Attitudes and objectives of local and State governments often are not the same. This has often hindered regional planning in the past and will do so in the future unless some common objectives and goals are established.

Land pollution problems of the past centered primarily on sediment, erosion, salinity, and forest and crop residues. As technology increased, a shift occurred to pesticides and animal wastes as land pollutants of primary concern. These will continue as problems for the foreseeable future. Recently, there has been increasing concern about heavy metals, such as mercury, lead, and cadmium. Although the R. & D. specifically directed toward heavy metals is small, other work on them included within the classifications of industrial wastes, solid wastes, and pesticides is substantial.

Requirements for fertilizer management systems that will keep water pollution to a minimum will increase with time. The question of obtaining sustained maximum production without causing enrichment of waters remains to be solved. The factors responsible for enrichment of runoff waters must be identified and evaluated.

The problem of disposal of urban wastes will intensify in the future if the pattern of increasingly greater urbanization continues. Assuming that it does, additional research is needed to determine the value of municipal compost for increasing crop yields, maintaining turf, and reclaiming or stabilizing barren soils; its value as a soil amendment, the capacity of the soil to accept large volumes of compost without adverse effects, and the views of compost users concerning the value and problems relating to compost use.

Integrated efforts among diverse scientific disciplines are needed to solve land pollution problems, which are expected to become more severe in the future. Because the capacity of the land to accept and assimilate pollutants is finite, increasingly greater attention must be given to recycling. The variety of land pollutants is diverse, their physical and chemical properties are diverse, and their effects on soil, surface and ground water systems, air, and the biota are diverse. Thus, the solution of problems will require a fully integrated, interdisciplinary effort.

There is increasing appreciation for the concept that no element of the environment is independent from the others. If that concept is accepted, the value of using mathematical and physical models and a systems approach to the solution of problems becomes self evident. In many cases, the fundamental information on which modeling and systems analysis are based is not yet available. However, complete information never will be available, there are merely relative degrees of adequacy. Thus, the lack of specific bits of information should not deter an accelerated effort in modeling and systems analysis. All disciplines and techniques should be brought to bear on what is now a difficult problem and has the potential for becoming more serious in the future.

Primary emphasis in the future should be placed on those pollutants that represent a potential hazard to man's health. Secondary consideration should be given to those pollutants that adversely affect man's welfare and his environment. Implicit in these primary and secondary considerations is the fact that our society does not permit tradeoffs in terms of human health. Where man's welfare or the environment is concerned, however, the benefits and risks of given practices must be weighed so that society realizes the greatest good at the least cost. To follow this broad definition of priorities will require a continuing analysis of land pollution problems. What is not known to be a health hazard today may become known as one tomorrow.

An attitude of environmental concern throughout society has been long awaited. Our concern must remain rational and progressive. The environment includes not only air, water, and land, but also the biological organisms, including man, that occupy the three media. Such a broad definition requires that our future activities be designed for the improvement of total environment. We cannot permit an overly protective attitude toward one component of man's environment if other components are adversely affected in the process.

CHAPTER 6

Understanding, Describing, and Predicting the Environment

The objectives of Federal R. & D. activities in this area are to provide the required understanding of the environment to permit man to fully utilize his environment and natural resources without degradation or destruction and to maintain good quality and esthetics. This requires a broad understanding of the environment, including climate, ecological processes, the effects of man, and a multitude of other interrelated factors. Predicting qualitative changes in the environment requires even more detailed knowledge of critical factors and processes and may require mathematical or physical models and long experience. Understanding, describing, and predicting the environment are all necessary to permit proper environmental management.

The areas that have been included are ecology and related research, environmental observation and measurement to describe and predict weather and oceanic activities, impact of environment on man, locating and describing natural resources, surveys to describe the physical environment, and weather modification.

The levels of support for this area have increased from $199.49 million in fiscal year 1969 to $249.99 million in fiscal year 1970, and to $323.52 million in fiscal year 1971. These funds are broken down by agency in table 6 (p. 39) and summarized in figure 6 (p.38).

ECOLOGY AND RELATED RESEARCH

Summary

Ecology is a broad subject; it may be used to include research in many areas or may be restricted as in this categorization. In a report entitled, "Advancing Scientific Understanding of Natural Plant and Animal Communities," published in 1968 by the Office of Science and Technology, the total Federal effort in ecological research, surveys, and education was estimated at $175 million for fiscal year 1966. The 1971 survey by the Office of Management and Budget, Special Analysis Office, showed an estimate of $99 million for fiscal year 1971. However, in this review of the programs, deletion of total facility construction costs and other factors considerably reduced the estimates to $41.50 million in fiscal year 1971.

Ecological research supported by Federal agencies includes basic studies on scientific understanding of natural plant and animal communities. This involves fundamental processes operating in and affecting plant and animal communities, impact of the communities on man, and the impact of man on the communities. Research is supported on comprehensive study of ecosystems that includes detailed studies of watersheds or other units of selected biomes. This research is included as part of the international biological program that is emphasizing the study of the biological basic productivity of various natural communities. The biomes being studied comprehensively include the grasslands, the deciduous forest, the tundra, the desert, the coniferous forest, and the tropical forest biome.

Much of the Federal research in ecology involves study of the effects of development projects and other programs conducted by the various agencies. This research includes studies on the effects of dams, dredging, changes of coastal areas, offshore engineering, transmission lines and highways, and wastewater facilities. Special studies are conducted on the ecological aspects of forest and range ecosystems as a basis for formulating management principles and cultural practices, particularly with multiple uses considered. Research includes the ecological effects of fire, wind, temperature, precipitation, overgrazing, and man's activities. Studies on the autecology of trees and range plants are conducted in relation to control of insect and plant diseases and for better

FIGURE 6.—FEDERAL R&D FUNDS

UNDERSTANDING, DESCRIBING AND PREDICTING THE ENVIRONMENT
by Program Area, FY 1969, 1970, 1971

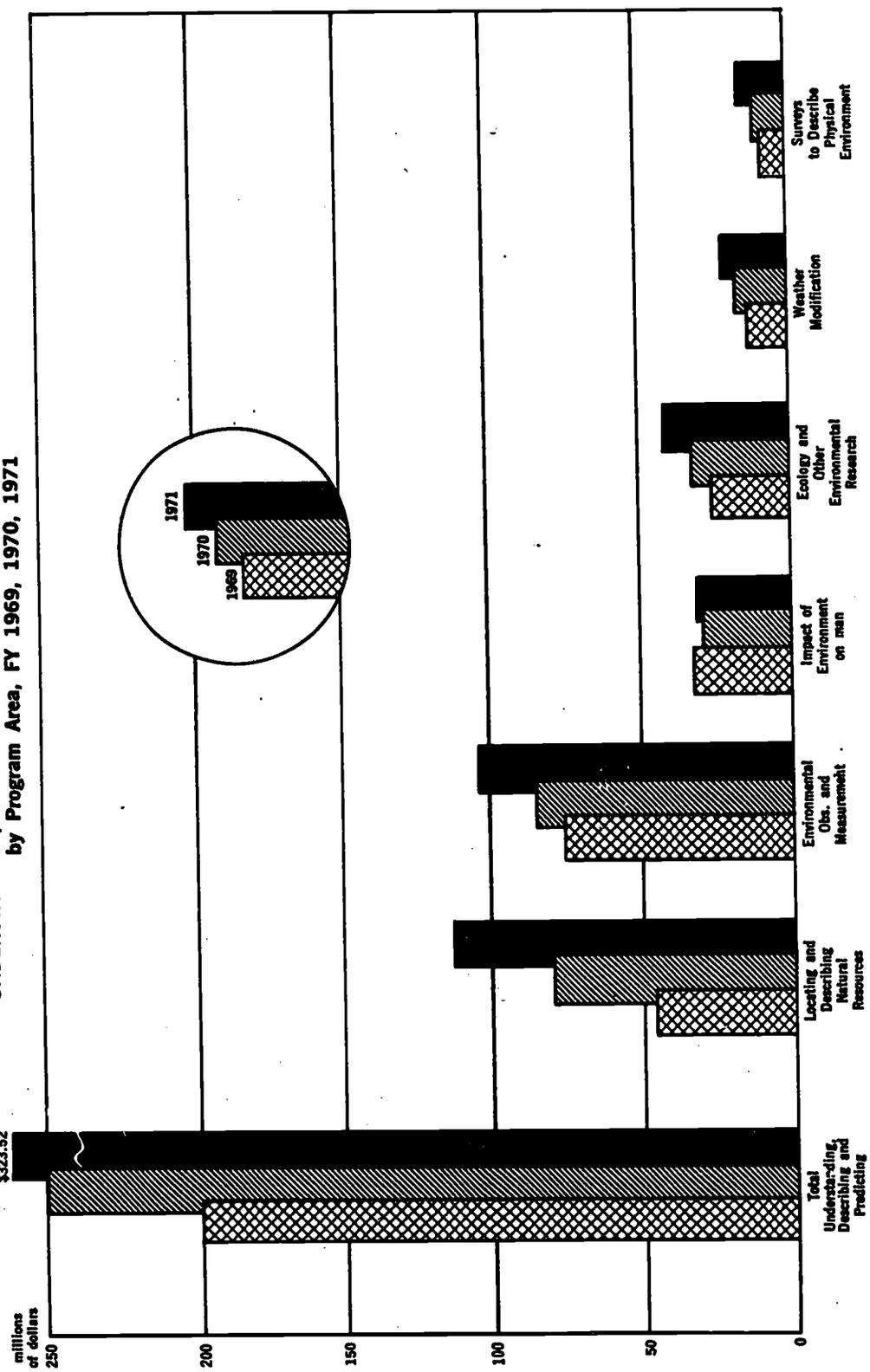


TABLE 6.—*Summary of funding for understanding, describing, and predicting the environment research and development by various Federal agencies, fiscal years 1969–71*

[Figures in millions of dollars]

Agency and fiscal year	Ecology and related research	Environmental observation and measurement to describe and predict weather and ocean	Impact of environment on man	Locating and describing natural resources	Surveys to describe physical environment	Weather modification	Total
CE:							
1969	3.30	2.00	0.20	.....	.....	.....	5.50
1970	4.20	2.30	.20	.....	.....	.....	6.70
1971	5.80	2.40	.20	.....	.....	.....	8.40
USDA:							
1969	3.81	.90	.....	4.74	.....	0.44	9.89
1970	4.17	1.00	.....	5.31	.....	.45	10.93
1971	6.48	1.02	.....	5.87	.....	.52	13.89
DOC:							
1969		19.70	.....	.....	1.90	1.30	22.90
1970		22.00	.....	.....	1.90	1.40	26.20
1971		35.50	.....	.....	2.00	1.40	38.90
DOD:							
1969	.40	8.59	.....	.....	.....	.90	9.89
1970	.70	13.87	.....	.....	.....	3.50	18.07
1971	.50	13.41	.....	.....	.....	4.70	18.61
DOI:							
1969	4.10	1.69	.....	28.09	1.64	4.70	40.22
1970	4.00	1.98	.....	31.82	1.83	4.80	44.43
1971	6.90	2.09	.....	32.17	2.00	6.50	49.66
DOT:							
1969		.....	.....	.....	.....	3.00	3.00
1970		.....	.....	.....	.....	2.30	2.30
1971		.....	.....	.....	.....	3.50	3.50
HEW:							
1969		.....	27.30	.....	.....	.....	27.30
1970		.....	23.60	.....	.....	.....	23.60
1971		.....	24.60	.....	.....	.....	24.60
NASA:							
1969		30.80	.....	11.10	4.00	.18	46.08
1970		30.00	.....	40.10	3.40	.20	73.70
1971		31.40	.....	71.10	4.40	.14	107.04
NSF:							
1969	10.80	10.01	2.30	2.30	1.00	2.70	29.11
1970	12.01	11.70	2.30	2.40	2.75	3.60	34.76
1971	14.32	17.00	2.80	2.90	7.00	4.50	48.52
SI:							
1969	2.90	1.00	1.70	.....	0	.....	5.60
1970	6.70	.40	2.00	.....	.20	.....	9.30
1971	7.50	.40	2.30	.....	.20	.....	10.40
Total all agencies:							
1969	25.31	74.69	31.50	46.23	8.54	13.22	199.49
1970	31.78	84.15	28.10	79.63	10.08	16.25	249.99
1971	41.50	103.22	29.00	112.04	15.60	21.26	323.52

productivity and management practices. Studies are carried out on various native and introduced species of insects, animals, and plants, and endangered species. Basic studies are supported on determining taxonomy of plant and animal species, and their distribution, abundance, and fluctuation in numbers. Ecosystem studies are being carried out in relation to human population increase. Studies on protected natural areas are conducted to determine the present composition of plant and animal communities to serve as baselines and benchmarks to measure and monitor the effects of increased population, pollution, and changes in the environment.

Analysis

Ecological knowledge is presently too limited and too infrequently applied to generate the political and social action required to resolve the serious environmental problems facing us. Ultimately, understanding the processes of renewability of resources underlies successful management of all ecosystems. An

intensive program of technology assessment is necessary to determine ecological and environmental effects of man's technology. A systematic program of environmental assessment is required to establish baselines, assess the state of ecosystems, and changes.

The trend today is toward increasing ecological and environmental R. & D. to help resolve the serious environmental problems facing us. An urgent requirement is to obtain accurate ecological and environmental data that require much greater support based on incomplete data. The trend in expenditures from 1969 to 1971 has been an increase from $25.31 to $41.50 million.

The priority of the ecological R. & D. programs is high based on statements by executive, legislative, and consultative groups. More funding support, however, has been given to action programs for immediate remedies to problems than to R. & D. in ecology.

Major present and future problems include the following: (a) Ecological and environmental goals and objectives with identified priorities need to be established. (b) Accurate baseline ecological and environmental data are urgently needed. Quantitative census and surveys of sensitive and vulnerable populations of certain plants and animals should be conducted to provide an early warning system. (c) The problems of ecology and environment are continually changing. Short-term, long-range, and second-order problems must be considered. (d) The complexity, change, multidisciplinary nature, and frequently critical data gaps make analysis of ecological data difficult. (e) An intensive program of technology assessment of environmental impact is needed to determine the rate of extraction of resources and return of wastes.

Integrating efforts and team approaches are absolutely essential in ecological studies to be able to develop a predictive capability. The complexity of ecosystems and the multidisciplinary character require large numbers of personnel working closely with integrating and system approaches. Nongovernment groups such as The Institute of Ecology have been proposed that could be of great value in helping solve many of these problems. Environmental R. & D. studies over wide areas require standardization of techniques, measuring devices, units, and methodology of analysis. The International Biological Program biome studies and the NSF regional environmental systems programs are an integrating influence.

Modeling and system approaches are essential to adequately measure, describe, and understand ecosystems and the environment. Both mathematical and physical models are being used to design experiments and to be able to understand ecosystems sufficiently to make predictions for management. The systems approach is essential to design experiments, to collect required data, and to handle and analyze it. In the International Biological Program, a level of integrated research using mathematical models and systems approach in studying biomes has been attained that can be considered a significant breakthrough. Multispectral remote sensing could contribute greatly to ecological studies using system approaches.

With the diversity of Federal agencies with some overlapping responsibilities, there is a potential for overlap that should be reviewed regularly. A comprehensive review of ecological research is required to properly evaluate the R. & D. effort and its effectiveness.

Gaps in R. & D. exist not only from lack of suitable support, but also because of limitations in our capability to measure, lack of instruments and techniques, and especially, not knowing the critical questions to be studied. A gap in baseline data exists because of our lack of accurate knowledge of the taxonomy, distribution, and abundance of the flora and fauna.

ENVIRONMENTAL OBSERVATION AND MEASUREMENT TO DESCRIBE AND PREDICT WEATHER AND OCEAN ACTIVITIES

Summary

R. & D. programs include eight Federal agencies with an expenditure of $103.22 million in fiscal year 1971. This is indicative of the extensive influence of climatic and marine environmental influences on a broad range of human activities. The major objectives are to understand the main problems of the atmosphere and ocean, to comprehensively describe and monitor these environments, to attempt prediction to avert environmental deterioration or catastrophic phenomena, such as severe storms and loss of life and property, and to permit proper management of marine resources.

The weather R. & D. programs include studies to measure and understand atmospheric processes and dynamics; simulation of their characteristic behavior and phenomena; and theoretical modeling. These studies will further the understanding of atmospheric processes necessary to develop capability for both short- and long-term weather prediction.

Research is carried out on cyclones, thunderstorms, and tornadoes to help in detecting, forecasting, and modifying them. Aeronomy studies are carried out to measure solar radiation at high altitudes and its effects on the earth's climate and atmospheric changes, heat balance, and effects of solar storms. Satellites are being used to measure atmospheric composition, circulation, and turbulence of the atmosphere, wind velocity, fronts, jet streams, cloud cover; to detect severe weather; and to issue appropriate warnings. Effects of weather are being studied on transportation, agriculture, forest fires, and phenology.

The marine environmental activities of the Federal Government have been described in a recent publication, "Federal Plan for Marine Environmental Prediction Fiscal Year 1972," published by National Oceanic and Atmospheric Administration (NOAA) in February 1971. The programs in this area are designed to gain a better understanding of the marine environment and associated phenomena necessary to develop and to use the resources of the oceans and coastal zones. These programs include integrated monitoring, marine prediction including timely warning of hazardous environmental conditions, and assessment and predictions of the distribution and abundance of living marine resources. A systems approach has been developed for marine weather prediction. Studies are underway on the important sea-air interaction involving energy and materials exchanges. Studies are also carried out on wave actions and their effects, thermal structure, coastal and ice dynamics, shore protection, and flood damage protection. Research is supported on movement of elements through the marine environment, through the marine food chain, and on their ultimate fate. Remote sensing techniques are being used in the study of sea state conditions, oceanic phenomena, such as upwelling and ocean currents, and locating fish schools and marine pollution.

Studies are sponsored on morphology, structure, and sedimentary processes of the continental shelf and of dispositional and tectonic processes occurring in the deep ocean basins. Shoreline reaction and changes produced by winds, waves, tides, storms, and depositions are being studied. Research is conducted on circulation of water, solids, and solutes in estuaries and lagoons and inflow of fresh water.

Analysis

R. & D. is carried out by eight Federal agencies. The budget has increased from $74.69 million in fiscal year 1969 to $103.22 million in fiscal year 1971. Most of the increase is due to the development of satellite observation programs.

Support for research on the atmosphere has not increased significantly during the past few years. Emphasis is needed in several areas including research to: (a) Understand the global distribution and long-term trends of the air composition and properties for pollutants of manmade and natural origin in relation to climatic change. (b) Understand the ocean constitutents, properties, and processes likely to influence climatic change. (c) Understand atmospheric motions, needed to improve prediction of local weather forecasting. The development of remote sensing of the atmosphere is important in this area. (d) Understand the global atmospheric and oceanic circulations and interactions to extend useful range of prediction in the 1- to 2-week period range.

Federal support of aeronomy has been slightly downward in the past few years. Most work in this field is conducted in-house, although considerable use has been made of special foreign currencies in supporting research overseas. While this program has not heretofore been directed toward environmental quality programs, the data and knowledge that have been obtained concerning the upper atmosphere will provide a baseline for measuring changes brought about by man's use of this region of the environment. There will be an important need for increased emphasis on predicting and measuring environmental changes that may be brought about by increased operational activities in this region, or by experiments involving the release of chemicals. Plans are being developed within NOAA for a modeling of the total solarterrestrial environment, including ultimately a modeling of the interface between the upper and lower atmosphere. Similar modeling of the behavior of atmospheric storms and molecules and their interaction with incoming radiation is underway. These will constitute important areas of emphasis with regard to environmental quality on a long-term basis.

Traditionally remote sensing, for example, radar, has played an important role in aeronomy. This role is expected to increase with the availability of new tools such as laser spectroscopy. Most data have been obtained from comparatively local regions. Increased emphasis should be given to the use of satellites as a platform for data acquisition on a global basis for assessing climatological changes in the upper atmosphere resulting from man's activities.

The Federal Plan for Marine Environmental Prediction, fiscal year 1972, published by NOAA in

February 1971 is an excellent summary of Government marine environment activities and plans. To accomplish the goals set, expansion of relevant R. & D. now in progress is recommended. This recommendation fits closely with that of the present analysis.

Federal R. & D. is being focused on the development of automated systems for obtaining marine, physical, chemical, and biological data. Studies are increasing on the major ocean current systems. In addition, there is an expanded effort to identify the nature and extent of secondary ocean circulations and to ascertain their relationship to the adjacent major current systems. There is also a continuing effort to develop new and major improved techniques for predicting physical oceanographic phenomena, such as sea state, mixed layer depths, and storm surges. There is a definite trend toward extramural research.

There are insufficient resources allocated to describing circulatory and diffusion patterns in estuarine and coastal waters. This is also true to some degree of the R. & D. effort in developing mathematical and physical models of estuarine circulation. There is also insufficient attention to the acquisition of data to develop mathematical models for predicting biological phenomena.

The present program is fairly well balanced. There is a current deficiency in the deployment of a data acquisition system to obtain physical, chemical, and biological data. However, plans are being developed to remedy this in the near future. There is an urgent need to concentrate on problems associated with the estuarine and coastal zones.

Pilot studies and experiments are needed in estuaries in which the total resources of the various agencies having some responsibility in this area are merged into one concerted effort. There is a need to develop an integrated marine environmental monitoring system in which the resources and capabilities of appropriate Federal agencies are utilized.

Preliminary modeling techniques are used to predict tides and salinity incursions in lower estuaries and also to predict sea state and storm surges. There is an urgent need by a wide variety of users for knowledge of the future state of the marine environment. Mathematical modeling is considered an ideal method for meeting this requirement on a systematic and timely basis. Longer time series data are needed to improve the accuracy of the model output.

There are some gaps in the monitoring of oceanic parameters and in the conduct of land-sea-air interaction experiments.

R. & D. in the future should be focused on (1) monitoring the marine environment and (2) developing prediction techniques for estuaries, major current systems, sea state, breakers and surf, sea ice, and marine biology. Further analysis is urgently needed on the physical, chemical, and biological aspects of estuaries and coastal water areas.

IMPACT OF ENVIRONMENT ON MAN

Summary

Man is shaped to a great extent by his environment. This includes his physical nature, mental health, culture, institutions, and even his survival. R. & D. studies are supported on the effects of environment on man and his physical surroundings and the modification of man's immediate environment in different climatic conditions. Research is also undertaken on the effects of environmental changes on man caused by human destruction and modification of environments.

A major part of the program is to determine what chemical, physical, or biological factors in the environment are likely to affect man's well being, to learn how these factors operate, and to provide the scientific basis for development of adequate control measures. Of great importance is the research on effects of agents acting in low concentrations over long periods, threshold and delayed responses, detection of subclinical symptoms, and defense mechanisms for enhancing resistance.

Research is also undertaken to determine the effects of environment on man with regard to his capability to operate under a wide variety of climatic conditions, and to provide adequate clothing, food, shelter, and other materials to permit him to withstand severe environments.

The effects of today's climatic changes on man are being studied as well as that in historical times using archaeological methods.

Analysis

R. & D. on the impacts of environment on man is being studied by four Federal agencies with $31.50 million in fiscal year 1969 and $29.90 million in fiscal year 1971. The subjects of industrial and occupational health and safety are not included in this report. These subjects must be considered in analyzing the R. & D. in this area. The effects of chemical,

physical, and biological factors in the environment must be considered in developing control measures. Of special importance are the effects of those agents acting in low concentrations over long periods of time. The effects of climate on man and man's modification of his immediate environment are being studied as well as the effects of environmental changes caused by human activities and changes of the environment.

Evaluating the amount and adequacy of coverage of research and development in such a broad area is difficult. Insufficient data are available on the effects of various environmental contaminants, such as the effects of low levels of DDT, mercury, cadmium, and other chemicals, especially over lifetimes or generations.

Other areas requiring investigation are the effects of crowding of human populations with the resulting pollution, social, and other stresses. Also required is the development of planning systems for maintaining or enhancing environmental quality in urban, rural, and neighborhood environments.

The degree of coordination between different agencies in this subject area is difficult to evaluate. Use of modeling and systems approaches are being attempted in urban and rural living areas.

LOCATING AND DESCRIBING NATURAL RESOURCES

Summary

R. & D. programs for locating and describing natural resources are being carried out by four Federal agencies with a budget of $112.04 million in fiscal year 1971. These programs do not include actual geological surveys, soil surveys, timber surveys, and other natural resource surveys, but include the R. & D. required for improving exploration concepts and techniques for locating new resources, or better evaluation of known and potential resources. Improved methods of survey, such as development of multispectral remote sensing including use of aircraft and satellites and ground truth verification studies, are being developed rapidly for surveys of mineral and oil resources, water resources, forests and rangelands, soils and nutrients. In addition to methods for survey and inventory of natural resources, research is conducted to monitor the changing conditions of resources including snowfall accumulation, flooding, range and forest degradation, including fire, insect, and disease outbreaks, effects of natural disasters such as hurricanes, and the rate of utilization of natural resources by man. More accurate maps are being produced permitting greater accuracy in assessing natural resources and their changes. Research is aimed at a better understanding of the basic processes that control the occurrence and movement of minerals and water. Methods are being developed to more accurately assess the future needs and trends in use of natural resources and of alternative uses of resources.

Analysis

Federal support of R. & D. for locating and describing natural resources has risen from $46.23 million in fiscal year 1969 to $112.04 million in fiscal year 1971. This increase is due principally to experiments on the earth resources technology satellites by NASA and some from the planned Earth Resources Observation Systems of the Department of the Interior. As stated in appendix 4, there are no costs of satellites, or launch vehicles included in these budget figures.

Large quantities of imagery data will require optimum sampling procedures and automation of readout, storage, and retrieval of natural resource information. An urgent problem appears to be the development of techniques for integrated multiresource inventories to supersede the single-resource inventories now made at different times. Such techniques would facilitate better multiresource management of the public lands and other large ownerships that is hampered by lack of in-place multiresource data. This applies especially to forest, range, mineral, and water resources.

Another urgent need is to expand research on the inventory of energy and mineral resources of the continental shelf.

Large amounts of funds are necessary to the conduct of multispectral sensing experiments in data acquisition to serve a variety of discipline interests. This is compared with the relatively low funding of other essential research such as in data analysis and interpretation.

Although experimental remote sensing programs can yield extensive information to assist in natural resources survey and environmental management, developing the great potential of these systems should be given high priority, as well. While some applications have already been made by using satellites, much basic research is needed on interpretation of ground truth and significance of spectral signatures for interpretation before the potential of remote sensing with satellites is fully proved.

Modeling of natural processes has limited application in locating and describing natural resources, but the systems approach is essential in developing the full capabilities of remote sensing. Systems development is also critical to the automation of storing and using natural resource data.

SURVEYS TO DESCRIBE THE PHYSICAL ENVIRONMENT

Summary

R. & D. on surveys to describe the physical environment is being conducted by five Federal agencies with a budget of $15.60 million in 1971. The programs involve research on the causes of earthquakes, mountain building, volcanoes, generation of tsunamis, and continental shelf morphology. Research indicates that the earth has large surface blocks or plates whose interactions appear to be responsible for earthquakes and other instabilities of the earth's crust. Research is being carried out to accurately locate these unstable areas, to determine stresses, and to develop earthquake predictive capabilities. Seismic recording instruments are being improved to increase accuracy of earthquake location and data handling.

Studies are sponsored on morphology, structure, and sedimentary processes of the continental shelf and of depositional and tectonic processes occurring in the deep ocean basins.

Analysis

R. & D. on earthquakes, volcanoes, and continental shelf morphology has increased from $8.54 million in fiscal year 1969 to $15.60 million in fiscal year 1971. Research on earthquakes appears to be progressing as a result of increased understanding of the basic mechanisms involving interaction of large surface blocks or plates. Predicting earthquakes in the future appears promising. No research was reported on subsurface thermal measurements and potential use in heat pumps for supplying required heating and cooling. This may be supported under other programs not relating to environmental quality.

No major overlaps were apparent. Coordination between Federal agencies appears effective. Although no modeling concepts were reported, they appear to offer real promise in the earthquake prediction.

WEATHER MODIFICATION

Summary

Weather modification R. & D. is being conducted to improve knowledge of precipitation phenomena and to develop practicable techniques for controlled modification of normal precipitation patterns. As this knowledge increases, the probability also increases of our capability to augment, redistribute, or alter the character of precipitation on a scale of national significance. The Federal weather modification program includes precipitation modification, fog and cloud modification, hail and lightning suppression, and severe storm modification. The research program is directed to developing an understanding of the atmospheric water processes and applying it to the development of techniques to solve problems caused by the behavior of atmospheric water. These problems include floods, droughts, hail, fog, lightning, hurricanes, and severe storms.

Analysis

The Federal weather modification program is a well-coordinated program involving seven Federal agencies with some joint projects. The budget in 1969 was $13.22 million and in 1971 was $21.26 million.

This program has made considerable progress. The state of knowledge and operational readiness is greater in some areas than in others, however, certain beneficial results can now be achieved.

A recent study by the Interdepartmental Committee for Atmospheric Sciences (ICAS), a standing committee of the Federal Council for Science and Technology (FCST), identified several areas where a national weather modification program may be of value to man's continued existence on this globe. These areas include precipitation management for water resources, reduction of damage from hail, lightning, and violent storms, and improvement of visibility in fogs.

Major scientific discoveries or "breakthroughs" are not necessary to achieve an operational weather modification technology. The basic premises have been generally verified and the remaining technological gaps identified. What is needed now is a firm commitment to the magnitude of development tasks involved in forming the practical and useful tool weather modification can be. Much remains to be learned of the basic meteorological processes that take place in the atmosphere, but the major thrust

now needs to be in extensive applied research coupled with associated research into the complex legal, social, economic, and natural environment considerations.

Close coordination among all interested agencies is maintained through frequent conferences, exchanges of experimental data and results, common sharing of some equipment, facilities, and computer programs, participation in joint experiments, and membership on various interdepartmental committees whose function is coordination of Federal activities in the atmospheric sciences. The establishment of specific cooperative multiagency efforts to resolve certain critical problem areas that impede the application of weather modification technology are needed.

The establishment of adequate mathematical models to describe and forecast the reaction of weather systems to weather modification applications are now under development and show considerable promise of providing this universal capability soon. Improved methods of evaluating the results of modification are expected to emerge from these basic model studies. Through mathematical modeling of large-scale circulations, the effects of long-term inadvertent modifications of the atmosphere by man will be simulated. However, increased emphasis should be placed on benchmark measurements, and research into this aspect of weather modification. Support for the establishment of a national depository for weather modification data is also needed.

Weather is a product of the atmosphere, itself a totally essential resource of mankind. The relatively new science of weather modification is one with the potential for vast economic and social gains for human life. All Federal agencies engaged in weather modification activities have the goal of manipulating the weather to better suit human goals and needs.

Man has been inadvertently modifying the atmosphere for years, by spewing forth great amounts of contaminants, exhausts, and heat without discrimination, and until recently, without concern for the consequences. The National Academy of Sciences cited this problem in a recent report, and said that "now is the time for an increased effort on a national scale in the fields of weather and climate modification. * * * It is important that the advances in research and development go forward with operational efforts and that new understanding of the atmosphere be quickly translated into operational methods which may benefit the whole of society." The Federal weather modification program is making good progress toward that goal.

Protecting and Enhancing the Environment

SUMMARY

The objectives of Federal R. & D. activities described in this chapter are to provide the scientific basis for actions which will: (1) Permit enjoyment and use of designated renewable resources without unacceptable impairment, and (2) lead to increasing the utility or value of such resources. Five major resource categories are recognized: Rural and wildland environments, fisheries and wildlife, recreation, urban and suburban environment, and water resources. An additional category, environmental systems, which relates to all the others, is also included. Total expenditures in fiscal year 1971 were $57 million, of which fisheries and wildlife resources absorbed the major proportion (60 percent). Activities relating to water resources, and to urban and rural environments combined, each represent about 18 percent of the total. The breakdown of the funding by agency for fiscal years 1969, 1970, and 1971 is given in table 7 (p. 48) and summarized in figure 7 (p. 47).

Analysis of Environmental Systems

This research involves a comprehensive approach to understanding the total complex of interactions between various technological activities and all the components of terrestrial and aquatic ecosystems. Its purpose is to provide regional resource planners and developers with a reliable prediction system that will permit them to identify environmental problems in advance and take steps to prevent their occurrence.

Fisheries and Wildlife Resources

R. & D. activities considered here are those concerned with protecting and enhancing the recreation, sporting, and esthetic enjoyment and commercial aspects of fish, birds, and animals. The continued renewal of our diverse and plentiful fish and wildlife resource is heavily dependent upon how skillfully their supporting aquatic and terrestrial ecosystems are managed. A major effort is aimed at acquiring knowledge of biological characteristics and requirements of oceanic and fresh water sports fisheries resources, and in understanding their relationships to their physical environment. Impacts of various types of manmade disturbances upon the aquatic environment and their consequences to fish populations are under study. Considerable research is also carried out on the distribution, life cycles, migrations, and natural enemies of important species. Other experiments are conducted on the persistence, detoxification, and cycling of chemical contaminants through aquatic ecosystems. Fish hatchery management and rearing methods are also being improved.

Wildlife research activities center strongly on management of the native habitat, with particular emphasis on the effects of timber harvesting activities. Considerable effort is also devoted to the study of big game on western rangelands. Other research emphasizes knowledge of the environmental requirements of waterfowl and other migratory birds. Principal emphasis has been on game animals and birds: plans for the immediate future call for more attention to nongame species, particularly those in the threatened or endangered category.

Recreation Resources

R. & D. activities are concerned with the protection and management of recreation resources, and with determining how they can best be planned and and developed to adequately serve public needs and to provide continued and increasing use without deterioration. Techniques are developed for projecting demands for various types of recreation activities. The potential contributions of recreation

FIGURE 7.—FEDERAL R&D FUNDS

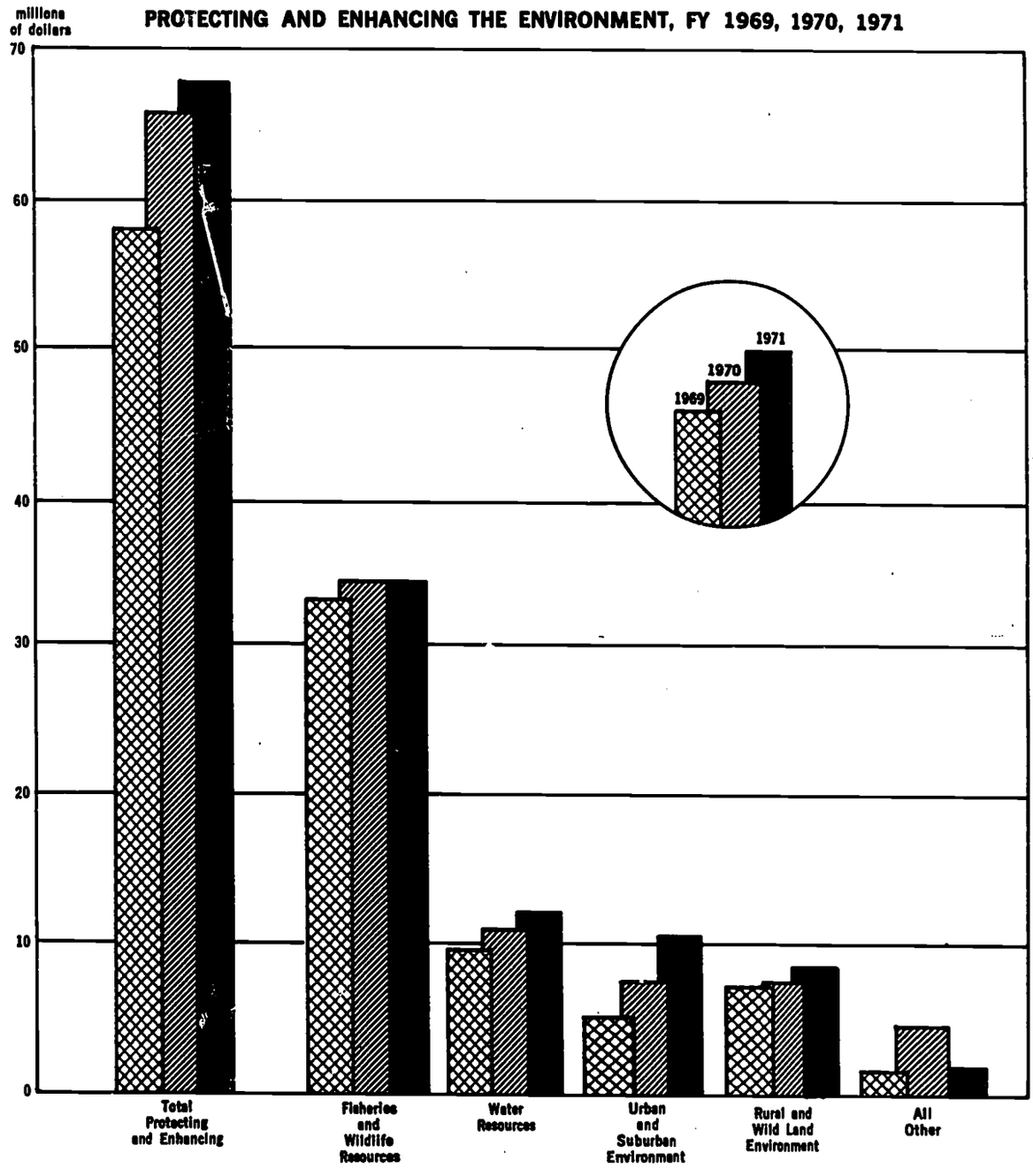


TABLE 7.—*Summary of funding for protecting and enhancing the environment research and development by various Federal agencies, fiscal years 1969–71*

[Figures in millions of dollars]

Agency and fiscal year	Analysis of environmental systems	Fisheries and wildlife resources	Recreation resources	Rural and wild land environment	Urban and surburban environment	Water resources	Total
USDA:							
1969		1.95	1.46	6.50	4.61	5.75	20.27
1970		2.22	1.55	6.78	4.95	6.12	21.62
1971		2.33	1.60	7.03	5.63	6.15	23.34
DOC:							
1969		14.22	----------	----------	----------	----------	14.22
1970		15.16	----------	----------	----------	----------	15.16
1971		13.15	----------	----------	----------	----------	13.15
DOI:							
1969		17.30	.10	.83	0	4.04	22.27
1970		17.20	.10	.91	0	4.79	23.00
1971		19.10	.10	.97	.45	5.07	26.59
DOT:							
1969		----------	----------	----------	0	----------	0
1970		----------	----------	----------	.65	----------	.65
1971		----------	----------	----------	.75	----------	.75
HUD:							
1969		----------	----------	----------	.77	----------	.77
1970		----------	----------	----------	2.09	----------	2.09
1971		----------	----------	----------	3.68	----------	3.68
NSF:							
1969	0	----------	----------	----------	----------	----------	0
1970	3.07	----------	----------	----------	----------	----------	3.07
1971	.11	----------	----------	----------	----------	----------	.11
Total all agencies:							
1969	0	33.47	1.56	7.33	5.38	9.79	57.53
1970	3.07	34.58	1.65	7.69	7.69	10.91	65.59
1971	.11	34.58	1.70	8.60	10.51	12.12	67.62

resources to the economy and quality of living in rural areas are being analyzed. Closely related studies are finding ways of making outdoor recreation resources more available and better suited to the needs and interests of low-income groups. Research on compatibility of outdoor recreation and other land and water uses provides the basis for multiple use management prescriptions. Management guidelines are also being developed and tested which will minimize adverse environmental impacts resulting from high-density recreation use. Although neglected in the past, increasing attention is now being given to determining the motivations, interests, and attitudes of people toward outdoor recreation activities and opportunities in order to assure a more rewarding and enjoyable experience for all. Greater emphasis on social and economic aspects of outdoor recreation is planned for the future.

Rural and Wild Land Environment

Practical and effective methods are being developed for managing land and vegetation for socially desirable objectives, as well as for the production of marketable commodities. This includes establishment, culture, and protection of windbreaks and shelterbelts in the Great Plains; modification of forest management systems to make timber harvesting compatible with the preservation of esthetic values; and the use of trees and ornamental plants for highway beautification and safety, screening of manmade landscars and eyesores, and similar purposes. A major effort is directed at the rehabilitation of strip-mined areas, mine waste embankments, and other situations where the land surface has been disfigured by industrial activities. Safe and effective ways of protecting scenic values of forests and other rural landscapes from fires, insects, and diseases are under study. Limited research is being conducted on rural land use planning for better resource-use allocation. More attention will be given to this important problem in the next few years. New and economically sound approaches to appraising intangible environmental values as a basis for land-use decisions will also receive more study.

Urban and Suburban Environment

The objectives of this research are to find ways of improving the livability, efficiency, and attractiveness of urban and suburban centers through better land use and planning, construction practices, natural resources management, more accessible recreation opportunities and open space, and more effective use of vegetation. Improved strains of ornamental trees, flowering shrubs, and turf, which are better able to withstand the unique stresses associated with urban environments, are being developed and tested. The design and layout of transportation systems are being approached from the standpoint of greater compatibility with overall environmental objectives as well as for improved efficiency. Ways of translating a variety of available environmental information sources and modes into forms useful to urban planners are being explored. Other research is establishing a sound basis for the location and design of open space areas in expanding urban and suburban developments.

Water Resources

The Nation's fresh water resource is an important and highly prized component of our environment, as well as a critical element of our industrial and domestic life. This resource is continually renewed through precipitation, but too much of what we receive is allowed to dissipate through lack of good resource management. R. & D. activities considered here are those designed to reduce evapotranspiration losses, induce greater infiltration and ground water storage, and in other ways make more efficient use of the annual supply. Rational and intelligent manipulation of vegetation, use of soil amendments, and careful scheduling of agricultural activities have substantial effects on the hydrologic cycle. Research is now underway to find ways of translating knowledge and experience into management systems which will have predictable beneficial impacts on streamflow and ground water recharge. Modeling procedures and computer programing are being utilized for developing quantitative projections of the hydrologic performance of watersheds under given management regimes. Land and vegetation treatments are being developed which do not create undesirable environmental side effects. Other important research involves describing and quantifying impacts of urbanization, highway systems, and irrigation projects on water yields. Institutional constraints to better water-use policies are being examined. Possibilities of upgrading or renovating waters impaired by industrial use are being explored. Undesirable effects of major water-development operations are being evaluated to find ways of minimizing deleterious consequences.

ANALYSIS

Study of recreation resources protection and enhancement has emphasized physical problems such as measurement of use, site deterioration, and resource management. The need for a better understanding of recreation user attitudes and preferences as a basis for resource planning and development is now being recognized. In recent years there has been a trend in fisheries and wildlife research away from conventional biological studies in favor of more emphasis on the effects of pesticides on reproduction and other life processes. This is likely to continue in the future. Research on wildlife, reflecting needs of and pressures by sportsmen, has been heavily dominated by work with game animals and birds. There are indications that more attention will be given in the future to nongame species, particularly those that are in a threatened or endangered status. The overriding urgency of water quality problems is likely to prevent any significant acceleration of research in the water resource activities reported here. In fact, some of the USDA efforts on water resource augmentation are now being reprogramed to problems of water quality.

Some research in urban and rural problem areas is of long standing and is obviously designed to improve quality of living. However, most of the activities reported are either of recent origin or represent incidental spinoff from research conducted primarily for other purposes. The fairly new HUD and DOT programs which have increased from $0.30 to $1.60 million in the last 3 years suggest an increasing realization that learning how to bring concepts of beauty and esthetics into urban planning is an important subject for research. R. & D. activities in the urban-rural areas reported by the Department of Agriculture are mostly mission-oriented, and contributions to environmental enhancement documented in this report are to a considerable degree the result of "indirect" research. This does not impair their usefulness or diminish their importance. However, if environmental needs and benefits were the primary rather than the incidental motivation, the

research might be more effectively planned and better staffed. All four Departments now engaged in urban and rural environment research, state their intent to give more attention to these needs. It appears that there will be greater "direct" effort allocated to important urban-rural problems in the future.

R. & D. programs reported in other sections of this report include numerous projects whose results will contribute to the enhancement of water resources and the improvement of environmental quality in urban and rural areas. Thus, it is not possible to make a meaningful evaluation of program balance between problem categories.

A serious imbalance exists between the size of the recreation research program and the complexity and magnitude of the job to be done. Outdoor recreation activities represent a $30 billion business, which is making rapidly accelerating demands and impacts on the resource. Outdoor recreation is becoming increasingly essential to the health, welfare, and enjoyment of life of all segments of our population. The present level of support ($1.70 million) for research falls far short of what is needed to provide the essential knowledge and technology to protect, develop, improve, use, and enjoy this resource. Because of the critical nature of the problems it is particularly important that allocation of the limited resources be guided by well-considered priorities. Part of the present effort can and should be reoriented to focus on some of the more critical and basic social and economic questions now receiving little or no attention.

Fundamental to the planning of a well-balanced research program is the question of prevention or correction. Should emphasis be on learning how to anticipate, predict, and avoid environmental impairment? Or should the main effort be to develop technology for correcting damage which has already occurred? The answer is obvious where disasters have already happened or are imminent. But it is rather easy for a research program to become overly committed to brush fires. Failure to give adequate attention to underlying causes and processes of environmental degradation may result in crises that are much more costly and more difficult to correct. Except for fisheries and wildlife activities, the programs reported seem to lack carefully planned and built-in balance between what are essentially long-term projects aimed at preventing and shorter term projects aimed at correcting environmental problems. This may be particularly true of some aspects of the urban and rural environment programs which seem to reflect a response to pressures and crises rather than a careful evaluation of problems and assignment of priorities.

The study of environmental problems, particularly those relating to urban, rural, and wild-land conditions, requires involvement of many disciplines from the physical, social, and biological sciences. The unique talents and contributions of engineers, meteorologists, sociologists, landscape architects, hydrologists, ecologists, systems analysts, and other specialists are required to adequately understand, and to develop technology to solve complex environmental problems. To be most effective, however, these skills must be carefully integrated and organized into multidisciplinary teams. Only in this way can interactions of plants, animals, weather, soil and geology, and man's needs and activities be observed, measured, and evaluated. For this kind of an integrated approach to be fully developed and utilized, much closer coordination will be required among agencies having responsibilities for different aspects of the same problem. Such coordination must go beyond the cycling of memoranda of understanding and statements of intent through the various agency hierarchies. Officials responsible for program planning must identify needs and opportunities for multidisciplinary research and must insist that project leaders work with their counterparts in other agencies at early stages of project development, and that joint, thoroughly integrated planning documents be prepared.

Much available information on resource protection and enhancement is not being used. More conscious effort is needed to bring existing knowledge together and to synthesize it into management prescriptions. Mathematical modeling is a versatile and powerful tool for this purpose if used with skill and ingenuity. This approach also can be employed to good advantage for resource impact evaluations where many environmental variables must be plugged in to predict effects of land use or treatment. Modeling procedures also can be adapted to the sophisticated social studies needed to develop a better understanding of people's attitudes, reactions, and motivations with respect to outdoor recreation and urban-rural environment.

Analysis of the information submitted did not reveal any significant overlaps or duplications in program activities. The DOI and the DOC have common interests and objectives in their investigations of pesticide effects on fish and the cycling of chemical contaminants through aquatic habitats. However, DOC is primarily concerned with estu-

arine and oceanic environments while DOI is principally preoccupied with fresh water, lake, and stream habitats. The respective responsibilities of USDA and DOI for fish and wildlife research are well defined and programs are closely coordinated. What is of more concern to the Committee than possible overlaps is the necessity for more coordinated planning, already referred to. More effort is needed in the future to insure better integration of research efforts and a reduction in the amount of fragmented and unrelated studies.

No major gaps, in the sense of significant areas of research completely untouched, were identified. However, there are numerous imbalances that should be corrected and important problems that are receiving only token attention. The most serious deficiencies identified are as follows:

1. A much stronger socioeconomic basis for planning, developing, and managing recreation resources is needed. Problems dealing with people—their behavior in, attitudes toward, and needs for outdoor recreation—are infinitely more difficult than physical and biological problems and have had little Federal funding support. Most of the limited amount of good research has been done by a few universities.

2. The limited amount of research on threatened and endangered bird and animal species needs to be expanded. Considerably more work should also be done on habitat requirements of nongame bird and animal species to enhance opportunities for their enjoyment through so-called nonconsumptive use. Some reprograming of funds and manpower from research on game animals and birds should be considered if new funding is not available.

3. More effort should be directed toward developing practical methods of managing aquatic ecosystems, perhaps at the expense of some of the more fundamental but low priority biological research, if necessary.

4. Most urban and suburban environments are now generally recognized by city planners as being cultural relics, which fail to meet even minimum standards for an acceptable quality of living. For renewal projects, urban expansion, and new city programs to rise above characteristic metropolitan blight, much in-depth research is needed to provide socially and aesthetically sound design bases for reshaping urban and suburban landscapes. This effort should include not only obvious aspects, such as provision for parks and other open space, but also for study of the integration of transportation systems, architectural modes, and land-use allocations. Parameters for measuring existing urban and suburban environmental quality and its rate of change should be established. Critically needed also are methods for identifying significant environmental factors and for evaluating between proposed environmental management alternatives.

5. Research on augmenting water resources by the manipulation of vegetation, particularly phreatophytes in the Southwest and high elevation forest stands in the Rocky Mountains, has produced a great deal of useful knowledge. High priority should now be given to applying this knowledge to the formulation of vegetation control prescriptions on an operational basis to determine overall costs and benefits, and to establish the reliability of water yield increase predictions.

6. Studies of the impacts of major water development projects should be extended to include overall ecological effects. For example, little is known of the influence of huge impoundments in mountainous areas on subsurface waterflow patterns, wildlife populations, microclimate, and ecosystem dynamics of adjacent slopes.

7. "A continuing dynamic program of land use planning" was called for by the Public Land Law Review Commission in its recent report. Legislation for a national land-use policy is almost inevitable. A stronger scientific base for land-use classification, both urban and rural, is needed. This requires a better understanding of land-use capabilities, ability to withstand various types of impacts, and the interactions of different combinations and levels of uses. Also lacking and badly needed by land-use planners and decisionmakers are procedural guidelines for calculating intangible amenity values for assigning proper priority to them.

8. The in-depth study of selected environmental systems, as affected by the entire complex of man's activities, has not received adequate support.

9. Finally, a great deal of the R. & D. activities reported here could benefit by more penetrating analyses of the problems themselves and a better definition of priorities established on the basis of specified criteria. The resultant programs should accurately reflect priorities, establish attainable goals, and provide for a more orderly and systematic development of knowledge that can be integrated into total problem solution.

CHAPTER 8

Special Studies

ALTERNATIVES TO THE USE OF PESTICIDES

Biological methods of control offer excellent opportunities as alternatives to the use of pesticides. Research in this field includes the search for and development of pathogens, insects, and higher forms of life, such as fish, for the control of weeds. For the control of insects, research is conducted on pathogens, predators, parasites, attractants and repellents, and radiation techniques to induce sterility.

Cultural methods of control are those that have been practiced historically in agriculture. They include such practices as crop rotation, crop-pest competition, cleaning fence rows, timed planting to avoid a pest, and water management for crops such as rice. These methods still constitute a significant part of pest control, but will seldom accomplish control objectives of themselves.

Mechanical control is also a historical method of pest control. As with cultural control, mechanical control is a significant part of pest management, but it does not usually afford adequate pest control of itself.

Breeding for resistance to pests has been most successful for the control of plant diseases and nematodes. The development of resistant varieties is the most important means by which yields have been increased without dependence on pesticides. There are only a few cases where a crop has been bred to provide resistance to a specific insect pest. Breeding programs are never ending. They require the continual development of new varieties to permit the rapid introduction of new genetic stock when resistance to a given pest is broken by the pest species. Thus, breeding for resistance cannot be done in anticipation of a problem. It can only be done after the problem is known.

Fundamental biology is essential for an understanding of pest control by whatever method. Detailed life history studies and physiologic profiles offer the basic knowledge of pests that is used in the development of specific control practices.

The trend today is toward a greater emphasis on biological and other nonchemical methods of control rather than the use of pesticides. The shift in emphasis has arisen in large measures because of public concern about the pollutant effects of pesticides. Despite an increased R. & D. in nonchemical methods of control, the need for regulated use of chemicals will continue.

Biological methods by themselves are unlikely to provide adequate control for very many serious pests in the foreseeable future, and the need for chemical control will continue. However, there is promise for the further development of integrated control using combinations of biological, cultural, mechanical, genetic, and chemical methods. This approach can substantially reduce the amount and frequency of chemicals used and in some cases may actually replace them.

For about 20 years after World War II, R. & D. on chemical pest control expanded rapidly. With increasing concern for the environment, a shift to nonchemical methods has occurred. The present balance in USDA between chemical and nonchemical methods of pest control, about 40:60, is consistent with the need for pest control in the future. The present thrust is to develop integrated control practices wherever possible so as to minimize the use of chemicals. Biological and other nonchemical methods of control are extremely effective and striking when they work. However, the hope for adequate control of most pests in the foreseeable future without the use of some chemicals is not realistic. Examples of the need for continued use of chemicals are the vastly increased incidence of malaria in Ceylon after the use of DDT was stopped and the damage caused by the gypsy moth in the United States after termination of control programs using DDT.

Integrated pest control has been talked about for many years. The concept is sound and should be put

into practice. True integrated pest control would require the close cooperation of scientists from various disciplines—entomology, plant pathology, weed science, ecology, and fisheries and wildlife biology. At the present time (1971) such scientists are segregated, for the most part, by organizational barriers. The breakdown of organizational barriers would not necessarily result in the close cooperation needed for sophisticated research on integrated control. Narrow scientific disciplines have been established for many years. The shift in educational emphasis on both undergraduate and graduate levels from narrow to broad concepts will probably be necessary before the interdisciplinary barrier can be effectively overcome.

Modeling and systems approach have not been widely used in pest control. Mathematical modeling has been used extensively in population biology and could be adapted to pest control problems. Remote sensing offers exciting possibilities. It is already possible to detect certain crop diseases and insect depredations by means of remote sensing techniques before these diseases and depredations are apparent to the eye. Remote sensing also could be used to plot weed infestations, especially those of aquatic weeds. There appears to be a reasonable potential for using remote sensing to determine when certain weeds are most susceptible. The latter possibility may be practical only on noncultivated areas. A systems approach to pest control is essentially equivalent to integrated control. Its use and utility have already been discussed.

A serious gap is the lack of detailed knowledge on fundamental biology of species and their interrelationships. Overlap is a far less important problem.

Attention in the future should be focused on integrated control. Concurrently, fundamental biology should be emphasized and proceed apace with the development of more refined control methods.

Table 8 (p. 53) summarizes the funding of R. & D. pertaining to alternatives to the use of pesticides for fiscal years 1969, 1970, and 1971 by each of the Federal agencies involved in such research.

TABLE 8.—*Summary of funding for alternatives to the use of pesticides research and development by various agencies, fiscal years 1969–71*

[Figures in millions of dollars]

Agency and fiscal year	Nonchemical pest control
USDA:	
1969	32.05
1970	33.64
1971	37.74
CE:	
1969	0.20
1970	.30
1971	.30
NSF:	
1969	.83
1970	.80
1971	.90
Total all agencies:	
1969	33.08
1970	34.74
1971	38.94

NOISE

Summary

Several Federal agencies are involved in R. & D. concerned with noise as an environmental pollutant. Noise abatement and control R. & D. may be categorized in terms of the medium which the noise pollutes—air, land, or water. Of the three, the program in air—devoted to the control of aircraft noise—is by far the largest.

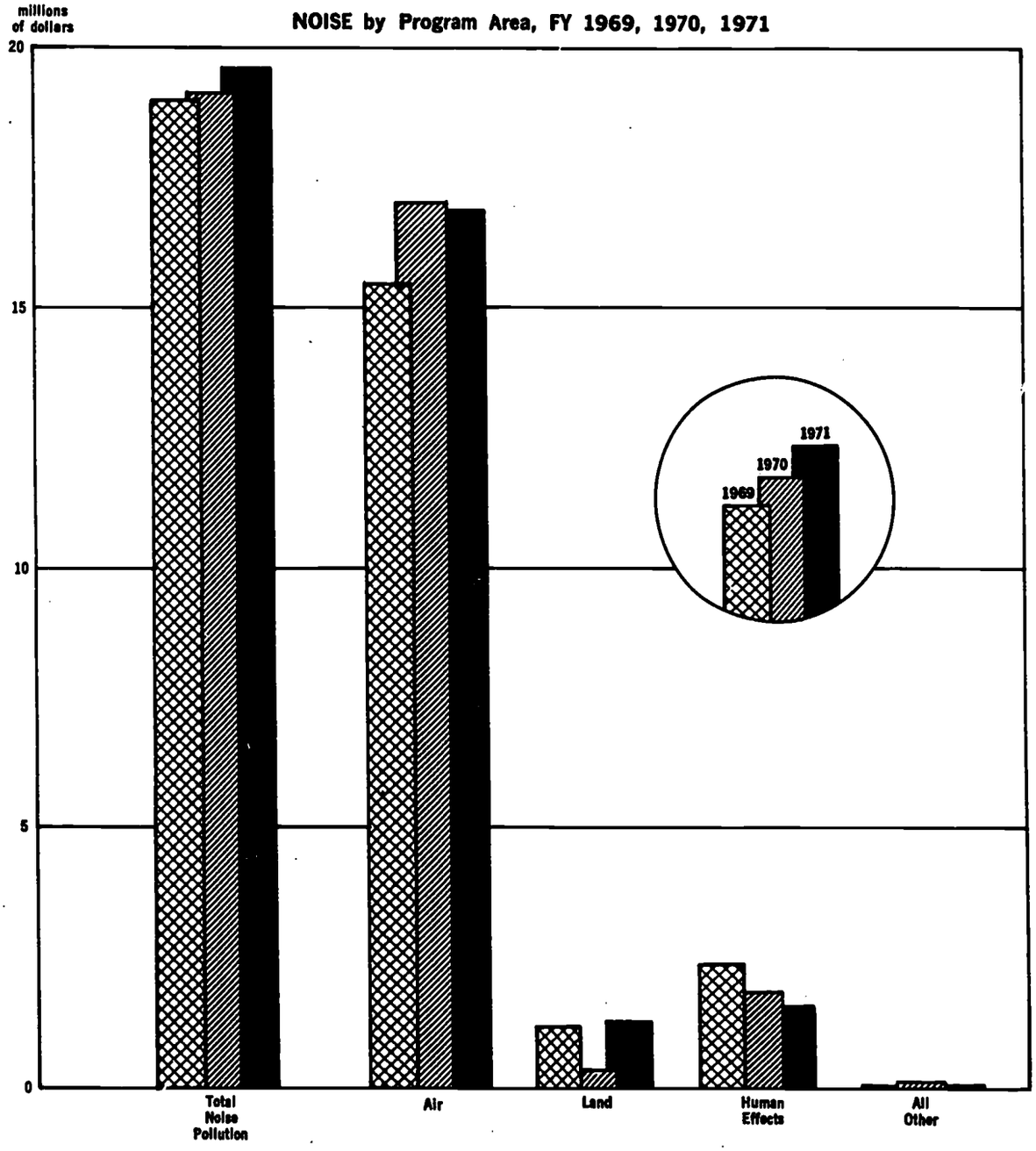
The noise pollution programs for each of the media may be described in terms of programs to reduce noise levels at the source or to reduce noise levels at the receptor by altering the noise propagation characteristics. An effort independent of the medium is that to determine the effects of noise on humans and their response to noise.

The information reported pertaining to noise has been divided into the following categories: Air, human effects, land, and water. The funding for each of these categories for fiscal years 1969, 1970, and 1971 is shown in figure 8 (p. 54). Table 9 (p. 55) summarizes the funding of each of these categories by each of the Federal agencies involved in R. & D. pertaining to noise.

The major funding efforts are centered in DOD, DOT, and NASA. Research emphasis has been placed on aircraft propulsion system noise and its suppression. Programs include quiet engine design, fan tests, nozzle configuration, supersonic jet noise, rotating blade noise, vertical takeoff and landing (VTOL) and short takeoff and landing (STOL) noise, propeller noise, reconnaissance aircraft noise, duct technology, and internal jet noise suppression. Sonic boom is being studied from the point of view of its generation and propagation as functions of configuration, flight path, and atmosphere. Research to re-

FIGURE 8.—FEDERAL R&D FUNDS

NOISE by Program Area, FY 1969, 1970, 1971



duce received noise through altered landing flight paths is also being carried out.

The DOC's National Bureau of Standards carries out a fundamental program on noise measurement methods and standards, including research on human response to noise, such as the annoyance value of different noises.

Two Federal agencies reported an R. & D. effort involving noise in water media. This combined minimal effort totals 366,000 for fiscal years 1969–71 and represents less than 1 percent of the total environmental noise program. The NSF grant-supported basic research on sound propagation has not been funded since fiscal year 1969. The DOT's R. & D. was sponsored by FAA and concerned the penetration of sonic boom energy into the ocean (completed in June 1970) and an investigation of underwater acoustic effects caused by atmospheric sonic booms.

Four Federal agencies reported R. & D. programs that have been categorized as noise and human effects. This category included approximately 4 to 8 percent of the total noise R. & D. effort.

TABLE 9.—*Summary of funding for noise research and development by various Federal agencies fiscal years 1969–71*

[Figures in millions of dollars]

Agency and fiscal year	Air	Human effects	Land	Water	Total
DOD:					
1969	1.36	0.95	0.10	----	2.31
1970	4.18	.51	.02	--------	4.71
1971	1.02	.60	.60	--------	2.82
DOT:					
1969	.98	.57	.93	------	2.48
1970	1.53	.44	.15	0.04	2.56
1971	1.23	.04	.46	--------	1.73
					[1](3.91)
HEW:					
1969	------	.05	--------	--------	.05
1970	------	.10	--------	--------	.10
1971	------	.20	--------	--------	.20
HUD:					
1969	----------	----------	.12	--------	.12
1970	----------	----------	.08	--------	.08
1971	----------	----------	.10	--------	.10
NASA:					
1969	13.12	.76	--------	--------	13.88
1970	10.63	.72	--------	--------	11.35
1971	13.77	.70	--------	--------	14.47
NSF:					
1969	.03	----------	--------	.03	.06
1970	.11	----------	--------	.04	.15
1971	.10	----------	--------	.05	.15
Total all agencies:					
1969	15.39	2.33	1.15	.03	18.90
1970	16.85	1.77	.25	.08	18.95
1971	16.72	1.54	1.16	.05	19.47

[1] Supplemental appropriation to FAA.

Emphasis has included physiological effects of continuous noise exposure, impulsive noise, infrasonics, noise and performance, acceptability of aircraft noise, personnel protection and communication, frequency resolution, hearing loss susceptibility, and nuisance and annoyance factors of noise exposure.

Analysis

Noise is an unwanted, undesirable sound without value. Noise is an environmental pollutant—a waste product generated by man and machinery. Noise pollution is considered by some to be on the verge of reaching a serious level and the awareness that noise is a significant factor in the degradation of environmental quality is generating R. & D. aimed at its control. Noise can be a hazard, an annoyance, and a nuisance. It can directly and indirectly affect man, plants, animals and structures. The Noise Pollution and Abatement Act of 1970 (title IV, Clean Air Amendments Act of 1970) focused attention on noise as a pollutant and established the requirement that a full and complete investigation and study of noise and its effect on the public health and welfare be undertaken. In September 1968, the Federal Council for Science and Technology identified and recommended a series of needs in its report "Noise—Sound Without Value" which this analysis shows have been met only in part.

Although several Federal agencies are involved in some aspect of noise pollution R. & D., the majority of the funding effort as reported is centered in DOD, DOT, and NASA. As would be expected, therefore, these programs are almost exclusively directed toward aircraft noise—its reduction, control and human effects and response thereto. NASA expends approximately 70 percent of all funds reported for noise R. & D. within the Federal agency programs. Average Federal funding for Noise R. & D. for fiscal years 1969 and 1971 was approximately $20 to $25 million per year.

Although the Federal Government has identified and is implementing R. & D. programs, needs and gaps remain. There is a need to develop guidelines for modification and possible retrofit of current aircraft. There is a need to develop noise certification for short takeoff and landing (STOL) and vertical takeoff and landing (VTOL) aircraft. The development of international sonic boom analysis and impact studies is proceeding. Operating procedures for aircraft noise abatement and refined guidelines for compatible land use planning need to be developed. New experimental approaches are underway to visu-

alize and analyze the complex phenomena involved in jet noise generation.

A need exists to conduct noise measurement, analyses, and information distribution to assist transportation system planners and operators.

Similarly, noise measurement and analysis of ambient noise levels in remote wildlife areas to determine impact of noise on wildlife is underway.

Transportation system noise measurements in metropolitan areas have been initiated to gather data that will be used to validate simulation models previously developed.

An investigation of truck tire noise as a follow-on to the current automobile tire noise investigation has been undertaken.

A program wherein highway noise enforcement problems could be examined to determine areas of possible refinement and develop innovative methods of noise measurement to assist local officials in enforcing State vehicle noise codes within urban areas.

Noise reduction pro. . ams designed to demonstrate economic means of abating noise generated by existing transportation vehicles should be developed.

A program to demonstrate economic and technologically feasible methods of attenuating noise transmissions generated by vehicles operating on highways or other guideways or both is in part underway.

A complete inventory of current truck noise performance should be taken, and noise reduction kits should be developed. These efforts could be used as the first step in the demonstration program on reducing truck noise.

Mathematical models of transportation noise reduction and attenuation are being refined.

Area-wide planning studies to consider the causes, trends, and the impact of aircraft noise on people and communities near airports should be expanded. The purpose of these studies would be to formulate applicable alternative policies that may be adopted to guide land use development in a manner compatible with forecast noise levels.

Long-term studies of psychological and physiological effects of noise on man need to continue.

Over the years little has been done to demonstrate means of abating noise generated by vehicles on our highways, hence, little has been accomplished by way of actual noise reduction, and many arguments primarily of an economic nature have been made against attempts at State and local highway noise enforcement programs. In addition, the need for mass transit vehicles to supplant the individual auto in congested urban areas will be taxing a substantial but diffused body of knowledge regarding the design and construction of acoustically acceptable mass-transit systems. It is, therefore, necessary in a priority fashion, to design and develop efforts to demonstrate the effectiveness of current and advanced state-of-the-art noise reduction as applied to surface transportation vehicles. This effort could also explore in a more cursory fashion the economic impact of such noise abatement technology in practice.

Initial effort should be aimed at demonstration projects for the most populous vehicles involved in the areas of largest community annoyance. As progress is made on the vehicles presently creating the most noise, other vehicles will begin to evolve as the most troublesome, hence, warranting demonstration projects of those vehicles in turn.

It is anticipated that the results of these vehicle demonstrations would permit and become the basis for progressively more stringent State highway noise standards. This, in turn, could provide the impetus for the inclusion of the technology developed within this research area as routine in the design and manufacture of vehicles.

Systematic research and demonstration evaluation programs should be supported with the intention of properly assessing current practices and developing new and innovative methods of attenuating noise transmission away from transportation rights-of-way. Specific areas to be explored are noise barriers (capable of being added to existing roads and designed into new roads), absorbent materials on retaining walls and abutments, roadside terrain contouring and planting trees and other vegetation, traffic flow control devices, and other design features.

In addition, techniques to aid highway noise enforcement could be developed to permit such enforcement programs close to urban residential areas and on highways employing noise abatement features.

The results of this research area would provide a direct input to State and Federal highway planners as well as State highway law enforcement organizations for immediate application within State environmental programs.

A continuing program of research into the fundamental aspects of noise generation and propagation should be supported as a source of new and more effective concepts of noise abatement theory and technology. Future development and demonstration programs would be able to draw on these concepts to inhibit the escalation of transportation noise in our society. While some efforts will pertain to scientific investigation of a generalized nature with such broad

potential application as to preclude identification of the research with specific transportation vehicles, it is anticipated that end results of all of the research would have specific application to transportation noise abatement and that such applications will be fully postulated.

Contributions of noises from interstate highway, airport, and major transportation terminal to overall ambient noise levels in urban areas should be further defined by building upon further measurements. Refined measurements would be made in accordance with a detailed plan formulated to ensure that sufficient data will be obtained to permit a factoral analysis.

Studies and analyses should be conducted to determine the feasibility of monitoring urban noise on a continuing basis to further identify contributions made by transportation vehicles. Based upon these measurements, demonstration programs of urban noise level monitoring could be initiated.

Analytical and mathematical models previously developed should be refined on a continual basis to provide more useful analytical tools for urban planners, vehicle manufacturers, and roadway builders.

Interrelated noise information services need to be provided in order that research and advisory information can be made available to appropriate State and local officials to assist in the establishment and enforcement of noise standards, planning, construction, and maintenance activities.

Little attention has been focused upon the effects of noise in water. With the concern of the Nation for the possible effects of sonic booms on transoceanic flight paths, there should be cause for more scientifically based data on the effects of noise and overpressure on various forms of marine life.

R. & D. is still needed to determine the hearing damage from different noise sources. Continuing R. & D. is required in human response to low-frequency noise, personnel protection, communication, and subjective responses to aircraft noise.

There would appear to be little if any overlap or duplication among the Federal agencies involved in noise control. Duplication could possibly exist in adapting the state-of-the-art from one noise source to another that is not completely dissimilar. It is also possible that R. & D. indirectly related to noise pollution control could be utilized in a more direct manner than is now apparently the case. It is also possible that R. & D. facilities and expertise in each Federal agency involved in noise control could be jointly used to a greater extent through interagency agreement and cross-funding.

RADIATION

Summary

R. & D. in the field of ionizing and nonionizing radiation is directed toward obtaining a complete understanding of the source, transport processes, physical, chemical and biological effects, singly or in combination with other pollutants on receptors in all media.

The information pertaining to radiation has been divided into the following categories: Evaluation of effects, measuring and monitoring, prevention and control, and transport and fate. The funding in each of these categories for fiscal years 1969, 1970, and 1971 is shown in figure 9 (p. 58). Table 10 (p. 59) summarizes the funding of each of these categories by each of the Federal agencies involved in R. & D. pertaining to radiation.

Evaluation of effects allows a better understanding of the immediate and long-term effects of exposure to ionizing and nonionizing radiation. A large part of radiation effects research is conducted at the cellular and molecular level in search of mechanisms of somatic and genetic damage and repair. These basic studies are highly relevant to the assessment of cause and effect of other toxic agents such as chemical pollutants.

Instrument development to measure and monitor radioactivity is an important part of this program. About $10 million is devoted each fiscal year (1969–71) to this effort, which involves the AEC, DOD, EPA, and HEW. This program supports several other Federal activity assessments of environmental radiation control and is a prerequisite to interpretation of radiological effects. Improved analytical techniques of greater sensitivity are being developed and investigated for application to a broad range of environmental problems.

Prevention and control technology R. & D. received the least funding of the categories addressed in this analysis. About $5 million for each fiscal year 1969–71 were identified. R. & D. devoted to improving the collection, handling, treatment, and disposal of radioactive wastes have been important parts of this program. Studies are also underway to develop procedures to reduce strontium-90 from nuclear fuel reprocessing plant aqueous effluents.

The AEC expended more than 95 percent of the funds allocated to all Federal agencies for R. & D. purposes. A substantial part of the work on transport and fate of radionuclides is funded by the AEC and accomplished by other Federal agencies. Interest in transport and fate studies stems from the fact that

FIGURE 9.—FEDERAL R&D FUNDS

RADIATION by Program Area, FY 1969, 1970, 1971

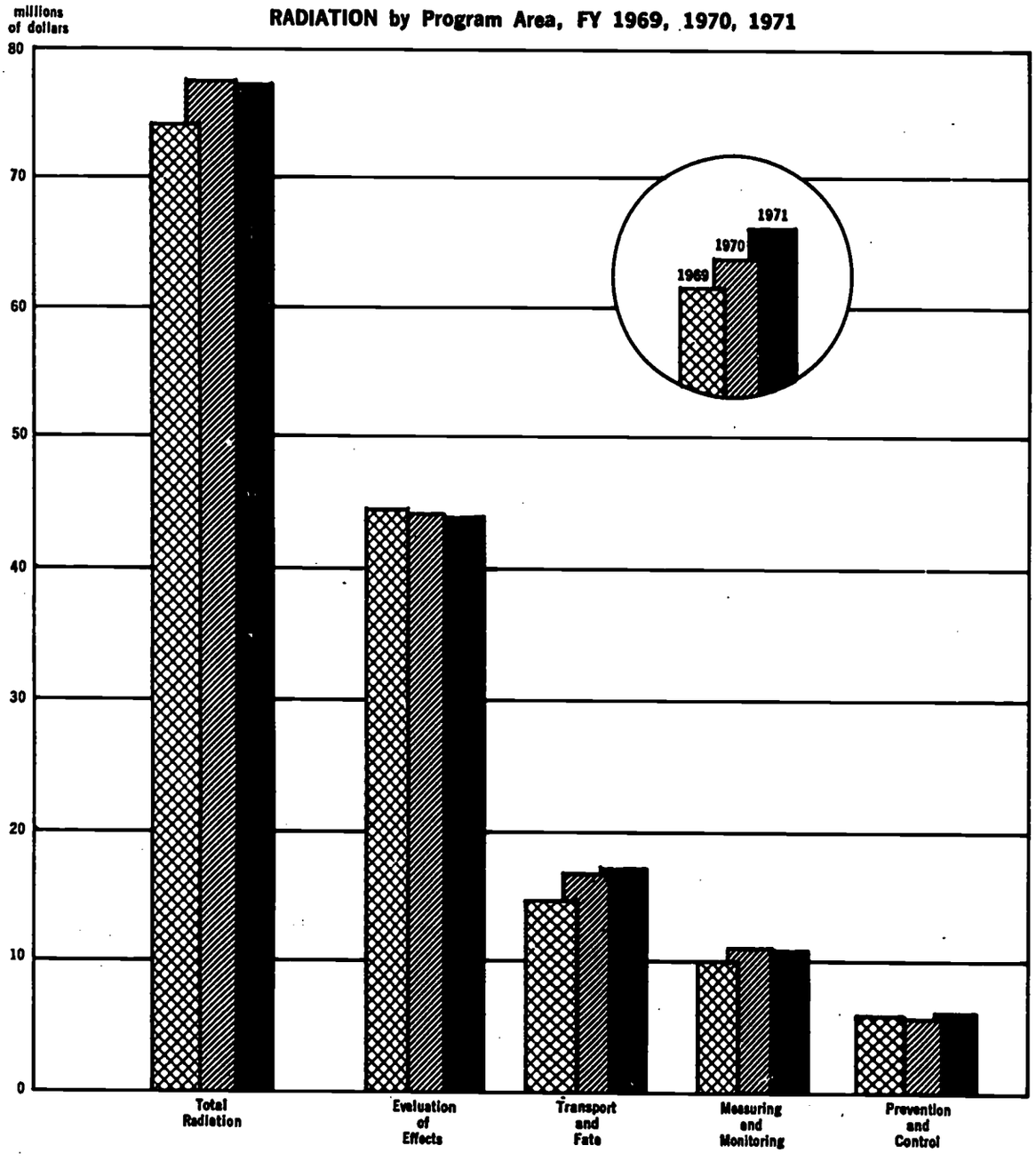


TABLE 10.—*Summary of funding for radiation research and development by various Federal agencies, fiscal years 1969–71*

[Figures in millions of dollars]

Agency and fiscal year	Evaluation of effects	Measuring and monitoring	Prevention and control	Transport and fate	Total
AEC:					
1969	40.98	8.72	5.08	13.89	68.67
1970	40.35	9.57	4.87	15.91	70.70
1971	39.59	9.37	5.12	15.11	69.19
DOD:					
1969	0.90	.20	----	.05	1.15
1970	.82	----	----	.01	.83
1971	.82	----	----	.01	.83
EPA:					
1969	----	----	----	----	----
1970	.28	.54	.02	.27	1.11
1971	.78	.59	.03	.96	2.36
HEW:					
1969	2.55	.70	.65	.35	4.25
1970	2.69	.85	.28	.28	4.50
1971	2.78	.79	.70	.40	4.67
NSF:					
1969	----	----	----	.22	.22
1970	----	----	----	.29	.29
1971	----	----	----	.32	.32
Total all agencies:					
1969	44.43	9.62	5.73	14.51	74.29
1970	44.14	10.96	5.57	16.76	77.43
1971	43.97	10.75	5.85	16.80	77.37

radioactivity may be introduced into the environment in many ways. The ability to understand the mechanism by which radioactive materials move through the natural environment is of paramount importance to this Nation and internationally. From these studies, it should be possible to predict reliably where and how rapidly such radioactivity will be transported. Approximately $16 million annually has been devoted to this R. & D. effort during fiscal years 1969–71. In addition to the AEC program, research is being supported by the DOD, EPA, HEW, and NSF.

It would also appear that the funding level for prevention and control technology is low when compared with the level of effort in other areas of work reported.

Although few Federal agencies reported R. & D. efforts currently underway in the nonionizing radiation area, some work is being accomplished involving microwave and laser exposure effects and standards development.

Urgently needed epidemiological studies on ionizing radiation should be undertaken. Low-level radiation exposure studies on young developing tissues are required. Along similar lines, fetal and organ sensitivity research efforts on humans and animals are necessary to provide knowledge that is still not available.

In nonionizing radiation, health effect studies and the development of measurement techniques are urgently required to assess the potential hazards of microwaves, UHF and VHF radiation, and radio frequencies in the general environment.

Analysis

The AEC is responsible for almost the entire Federal program of R. & D. related to radioactivity. Some mission-oriented work is being accomplished by several other Federal agencies, including the DOC, DOD, EPA, and HEW.

R. & D. is still necessary to reduce the discharges of radioactive material to the environment. Increased research on the biological effects of low-level radiation is required to further investigate the adequacy of existing standards. Investigations are still needed to assess transport and fate of radionuclides through the land and water environments. Although land-disposal techniques are acceptable alternatives to ocean disposal, this area must receive additional emphasis in light of President Nixon's recently announced national policy on regulated ocean dumping and proposed legislation currently before Congress.

POPULATION

The Distinction Between Population Research and Environmental Research

This report discusses the ways in which population factors (current numbers and distribution of people in the United States, historical trends, and projections) seem likely to affect the quality of our physical environment. In particular, the Committee has attempted to identify Federal R. & D. activities that specifically relate the growth and distribution of population in the United States to the pollution of the air, water, and land—pollution that directly affects our health and the esthetic quality of our lives.

At the outset, the reader should be warned against the pitfalls involved. There is a popular but grossly oversimplified idea that the best way to control environmental pollution is to reduce population growth as rapidly as possible and to stabilize the population at some optimal level. Some observers have suggested that this level should be even smaller than

the present U.S. population of 205 million. It is true that a growing population may aggravate our environmental problems simply because an increased number of people will consume more goods and generate more wastes. However, while precise data are frequently lacking and estimates vary with specific pollutants and the specific vector (air, water, land), pollution in the United States has increased much faster than population. The bulk of the increase in pollution must be attributed to our use of the Nation's economic abundance for industrial and technological development and to individual consumption, disposal, and behavioral patterns.

While population growth per se is thus not the major contributor to environmental pollution in the United States, the increasing concentration of our population in metropolitan areas does have profound and often adverse effects, both on urban areas and on rural areas, which over the past decades have been continuously losing population.

In addition to the distracting noise levels and frustrating congestion that seem to characterize most of urban life in America today, the pollution of the water and air and the accumulation of garbage, junk automobiles, and industrial wastes in metropolitan areas are all too visible and familiar phenomena giving rise to increasingly loud cries of public outrage. The high concentrations of population in inner cities and the suburban rings surrounding them have as their concomitant a concentration of effluents associated with the general affluence and the high levels of energy use and product consumption Americans enjoy.

It should be made clear that attempts to influence birth rates or to reverse the ongoing concentration of population are no substitute for direct and sustained efforts at reducing per capita pollution of the environment, disposing of unavoidable waste products, and systematically altering existing technology so that our waste products are less hazardous to man and other living species.

The Commission on Population Growth and the American Future was established in March 1970 and is scheduled to submit its final report to the President and to the Congress in March 1972. Among other things, the Commission will consider whether or not there should be established a policy aimed at population stabilization, the ways in which population stabilization should be achieved and maintained, as well as the demands for jobs, housing, schools, transportation, and other amenities that are likely to be imposed by the additions to our existing population which can be expected between now and the turn of the century. At present the U.S. Government has no official policy for controlling either population growth or population distribution. Obviously, the report of the deliberations of the Commission will be important to those agencies concerned with environmental planning and environmental policy. However, for reasons pointed out above, the recommendations of the Commission cannot be reasonably expected to solve our very real environmental dilemmas.

With the enactment of the Family Planning Service and Population Research Act of 1970, the Federal Government has committed itself to a policy of providing family planning services for poor people desiring such services. In addition, the act provides for information and education efforts to the general public about existing methods of contraception and where the necessary services, devices, and materials can be obtained.

Irrespective of the overall impact on population trends in the United States, the act itself does not constitute nor is it intended to constitute a population control policy, let alone a policy to enhance our control over environmental pollution. It does, however, provide for an expansion of population research, parts of which in the behavioral and social sciences may be related to (but are not synonymous with) research and development efforts on environmental quality.

The Importance of Demographic Data for Environmental Purposes

While demographic research per se is not a subdivision of environmental research and development, it is necessary to underscore the need for accurate data about existing status and historical trends in regard to both population size and distribution. Such accurate data are the basis for improved projections which environmental planners and policymakers must rely upon in arriving at their own projections of total pollution load, resource depletion, and ecological impact. The activities of the National Center for Health Statistics in collecting and analyzing birth, death, marriage, and divorce data coupled with the decennial census and related activities of the Bureau of the Census provide the best existing quantification of several key variables in the scientific study of man in relation to his environment. These descriptive demographic data have such multiple uses, encompass so many social concerns, and

are used by so many Federal agencies that their importance is sometimes overlooked in problem-oriented task forces, and their future availability and excellence may unwisely be taken for granted.

In periods of budgetary austerity there is a danger that we will cut back unwisely on the support of important descriptive activities such as those of our general statistical agencies in favor of "targeted" research on problems of urgent public concern. Therefore, environmental specialists, along with other action-oriented agencies and groups, must recognize that it is in their own self-interest to advocate continuing Federal support of these general demographic activities. Without these statistics, many of their own necessary calculations will become impossible and projections will become increasingly unreliable.

Definition of Pertinent Research

This report includes only population research related directly to domestic environmental quality and includes specific details on only those research projects that explore the impact of population factors on the pollution of air, water, and land. The Committee sought to identify as completely as possible federally sponsored or conducted research on (1) population size (growth) as it affects environmental quality; (2) population distribution and density as it affects environmental quality; and (3) the relationship of population characteristics to per capita contribution to physical pollution of the environment.

It is necessary to apply strictly construed criteria in identifying population research relevant to environmental quality. To do otherwise would obscure the focus of the overall report by including virtually all demographic research, contraceptive development activities and a wide array of fundamental reproductive biology, operational research on the delivery of family planning services, factors affecting family size perferences and many other types of studies.

Sources Reviewed in the Search for Federal R. & D. Population Environmental Interrelationships

The major published sources for Federal population research are:

- *The Federal Program in Population Research.*—A report to the Federal Council for Science and Technology prepared by the *ad hoc* group on population research, U.S. Government Printing Office, July 1, 1969.
- *The Federal Program in Population Research.*—Inventory of population research by Federal agencies during the fiscal year 1970, prepared by the Center for Population Research, National Institute of Child Health and Human Development, U.S. Government Printing Office, December 31, 1970.
- *Population Growth and America's Future.*—An interim report prepared by the Commission on Population Growth and the American Future, U.S. Government Printing Office, March 16, 1971.

Federal Research and Development Activities Concerned With Population Environment Interrelationships

Only a small number of Federal research projects were found whose avowed purpose was to relate population factors to environmental quality. One series of efforts now underway is sponsored by the Commission on Population Growth and the American Future. Under contract with the Commission, Resources for the Future will conduct studies on the basis of which they "will advise the Commission as to what patterns of population growth and distribution would be consistent with rational use of resources and the environment, as well as how the Nation might accommodate increasing numbers and/or density of population without exacerbating existing resources and environmental problems." Among topics being investigated by Resources for the Future, the following seem particularly germane to population/environment interrelationships:

- Developing a conceptual framework that would separate demographic factors from other determinants and provide a basis for assessing the sensitivity of environmental quality and resource demands to these factors. In addition, the framework will seek to isolate effects due to population growth and those due to population redistribution;
- The implications of population growth and distributions for several types of pollution—air, water, and land pollution. Waste disposal and byproducts of energy consumption will be investigated to illustrate how population growth might play a role in each of these types of pollution; and

- The resource and environmental consequences of various changes and technology and/or institutions as they modify the impact of population growth.
- The implications of population growth and distribution on future recreation demands and resources.
- The implications of population growth for future energy demands and resources.

In support of these efforts, Resources for the Future is expected to allocate at least 30 man-months of professional staff time and to contract outside its own organization for five research projects costing an average of $5,000 each.

As part of its efforts in civil works, the Army Corps of Engineers has supported at Harvard University three related studies costing a total of approximately $100,000 which attempt to relate population factors to environmental impact. These are as follows:

- "A comparative study in resource analysis methods." The study compares 60 methods of analyzing water resource projects including land use and ecological effects, population growth, and population distribution.
- "A systems analysis for planning a multiple use of control water areas." An investigation of ecological impact from recreation-oriented watersheds. Recreation needs are quantified, and, given the reservoir location to satisfy these needs, the impact upon the ecology is measured.
- "A study of resource use in urbanizing watersheds." The study includes "***a model constructed to enable planners to evaluate quickly the damaging impact of urbanization (and changing land uses) on the runoff characteristics of a river basin."

These were the only Federal projects found which related population factors to their effects on environmental quality. The Commission on Population Growth and the American Future has asked some American scientists to prepare reviews and speculative papers on population/environment. These are discussed below in connection with environmental/population research needed.

Department of Agriculture

The Population Studies Group in the Economic Research Service is particularly interested in rural-urban demographic trends. Some of the projects carried out under the auspices of the Agriculture field stations produce population-related data for small areas, which may be helpful to agencies responsible for environmental control activities in those particular areas.

Department of Commerce

The Census Bureau performs special analyses and studies under contract to various Federal agencies, including many agencies with environmental responsibilities. This shows the expressed need for sound demographic data in planning and mounting programs to control pollution and enhance environmental quality. The decennial census of population, the census of housing, and the census of manufactures also provide an essential data base for dealing with a variety of environmental concerns.

Environmental Protection Agency

EPA undoubtedly will be interested and involved in research efforts that view population factors as independent variables and various types of environmental pollution as dependent variables. However, no such studies have been identified as underway by EPA at the time of the present review.

Department of Health, Education, and Welfare

The National Center for Health Statistics collects and analyzes birth, death, marriage, and divorce data. These data are keystones in comprehending and projecting population trends in the United States. The Center for Population Research in the National Institute of Child Health and Human Development has launched an extended social science research program in population. Particularly relevant to environmental concerns is the fact that the Center for Population Research is attempting to stimulate and is prepared to support competent research on the ecological and environmental impact of population growth and of urban and industrial development coincident to population changes.

National Science Foundation

The Division of Social Sciences and Human Resources of the Research Applications Directorate is one that can potentially support some kinds of complex research on the interface between human population problems and environmental problems. In addition, both the ecology and social science research activities within the Research Directorate of the

National Science Foundation might logically involve the same human population-environment interface.

State Department—Agency for Internation Development

The Agency for International Development has a large research effort in population and family planning which also addresses itself extensively to the relationship between population factors and economic development in the less developed countries of the world. However, pollution control has not been a major emphasis of the population research program of AID and since the program is oriented exclusively toward nonindustrialized foreign countries it is not directly applicable to domestic environmental protection efforts.

Commission on Population Growth and the American Future

The Commission, which has a 2-year mandate terminating with a final report in March 1972, is for the time being the key Federal group addressing itself specifically to population-environment interrelationships. Its ongoing research efforts on this topic were described earlier in this chapter and the final Commission report should provide useful findings and suggestions for research crucially needed on this topic.

Other Federal Agencies

A number of other Federal agencies use population data for their varied responsibilities but do not currently have major research and development programs focusing on population-environment interrelationships per se. The Corps of Engineers' civil works, The Department of Housing and Urban Development, the Department of the Interior, and the Department of Labor need population data for planning their activities, many of which can affect environmental quality.

Research Needed on Population-Environment Interrelationships

The pervasive and complex problems involved in either population or environmental phenomena require sustained and systematic scholarship and research to improve our comprehension of these important subjects. When the interfaces between population phenomena and environmental phenomena are considered, the intellectual and scientific challenges involved become greater than ever.

The Commission on Population Growth and the American Future discussed some of these challenges in chapter 3 of its Interim Report dated March 16, 1971. The Commission observes in its report that "to consider population growth or concentration as the root cause of our Nation's social and environmental ills is clearly simplistic ***rapidly rising levels of per capita consumption and technological mismanagement appear to contribute more to environmental pollution than does a gradual rise in total population." However, they aeknowledge, "ever though population growth is not the primary cause of environmental deterioration, it may well magnify problems arising from the way we use our resources and technology." For this reason, the Commission report says, "economists and ecologists have been enlisted by the Commission to determine the effects on the environment of population growth, technological change, and changes in demand resulting from greater affluence."

With respect to the distribution of population, the Commission report notes "a large city might actually be better able than small communities, to afford ecologically sound solutions to many environmental problems. So simply redistributing the population might not solve many of the population-related problems we face."

There is a need for valid data and greater understanding about the synergistic effects of economic, technological, demographic, and other social factors on environmental quality. In addition to the work being undertaken at the request of the Commission on Population Growth and the American Future, the Center for Population Research, the National Institute of Child Health and Human Development, has publicized its ability and eagerness to support meritorious and innovative research that promises to shed light on the population-environment interface—a subject about which there is currently far more controversy than reliable knowledge. Their request for research proposals states: "The interrelations between population, technology, and industrial development are in particular need of clarification to guide the formulation of policies with reference to environmental quality."

A number of scholarly papers have appeared in *Science* on the relationship between population and environmental quality and one theme of the December 1970 meetings of the American Association for the Advancement of Science was population-

environment interrelationships. Both the scientific community and the Federal Government are beginning to delineate some of the practical and theoretical issues on which research is needed. Such research will probably require heavy investments of Federal dollars in the near future because of the complex nature of the phenomena to be examined, the variety and number of scientific and technical disciplines that will have to be involved in such investigations, and the high degree of expressed public concern about the environmental ills that threaten and disturb us all.

Air Quality

Funding of R. & D. pertaining to air quality for fiscal years 1969, 1970, and 1971 is reported in table 3 (p. 19).

EVALUATION OF EFFECTS

Atomic Energy Commission (AEC)

In addition to the effect of radioactivity (described in the special studies—radiation section) the AEC research program addresses the effects of waste heat from power generation and usage on the environment. In a cooperative effort with NSF at St. Louis, the effects of waste heat and air pollution on urban diffusion and on precipitation are underway.[6]

Department of Agriculture

The objectives of USDA's research program are (1) to determine physiological, biochemical, and pathological effects of air pollutants, singly and in combination, on growth and productivity of field crops and horticultural plants; (2) to devise methods for protecting plants from air pollutants, including use of genetic, chemical, and cultural control; and (3) to find methods of assessing the efficiency of plants in removing air pollutants. Results include the development of facilities for assessing the response of plants to air pollutants. Some resistant plants have been identified. Studies have also investigated the effects of ozone and ethylene.

Funds (in millions of dollars) expended by USDA for evaluation of effects during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
1.31	1.36	1.44

[6] Funding for this AEC program has been included in the totals listed in the special studies—radiation section of this report.

Department of Health, Education, and Welfare

The Carcinogenesis area of the National Cancer Institute carries out a continuing program of animal bioassay for the assessment of environmental hazard resulting from chronic exposure to a variety of air pollutants. Under study at this time in animal systems are a variety of polycyclic hydrocarbons and related heterocyclic compounds found in urban atmospheres, tobacco smoke and smoke condensates, asbestos, metal oxides, and a number of other airborne dusts.

To carry on this program, it has been necessary to establish a resource for the production and characterization of fine particles having a high degree of purity and physical uniformity.

Funds (in millions of dollars) expended by HEW on evaluation of effects during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0.20	0.34	0.23

Department of Transportation

DOT is investigating the effects of exposure of people to concentrations of aircraft engine emissions with respect to physiology, discomfort, or annoyance. Also studied are the effects of various concentrations of such emissions and fallout of particulate matter on property. DOT has also initiated a research program to provide standards for environmental quality in the areas near airports. Future plans include the implementation of operating standards based on the research conducted.

Funds (in millions of dollars) expended by DOT on evaluation of effects during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0	0.05	0.24

Environmental Protection Agency

EPA's research program on the effects of the common air pollutants was reported by the Air Pollution Control Office. The objectives of this R. & D. are to determine the impact of air pollution and air pollution control on man and the environment and to provide the scientific basis for air quality criteria and standards for the major air pollutants.

Among other accomplishments, EPA research in this area has contributed to the scientific and technical base from which air quality criteria reports have been developed for sulfur oxides, particulates, carbon monoxide, hydrocarbons, and other major pollutants. Criteria documents form the basis for air quality standards.

In fiscal year 1971, the Agency is conducting R. & D. on the effects of air pollutants, either singly or in combination, on livestock, vegetation, the food chain, and selected natural ecosystems. Several studies on the effects of air pollutants on economically important materials, such as paints and rubber, are in progress. The social and esthetic impacts are being studied. Two reports on odorous compounds and visibility will be prepared. Several reports on the economics of air pollution, such as the cost of clean air, cost to industries, and control by incentives, are to be completed in 1971.

Studies are also being conducted on the effects of SO_x, CO, particulates, NO_x, oxidants, hydrocarbons, and trace metals, singly and in combination. Research on chronic exposures to low levels of these contaminants and studies to determine the threshold limits for short-term exposure are also being conducted.

A 5-year plan to delineate the air pollution aspects of urban transportation planning activities is being developed. Guideline documents concerned with roadway design and alternative transportation systems will be issued in fiscal year 1971 to assist city transportation planners in minimizing mobile source pollution.

Under the Community Health Effects Surveillance (CHES) program the following will be accomplished in fiscal year 1971: Feasibility studies to determine the most sensitive indicators of health status of populations; extension of the CHES program into three additional cities; continued surveillance of health status of exposed population in relation to particulate air pollution levels; and continued collection of baseline data of health in New York City to study the effect of improving air quality in future years.

Future work in this area will include research on the environmental effects of pesticides and trace elements. Several studies of the economic effects of air pollution on materials will be pursued, and an in-house laboratory capability in this area will be developed. Other research will include studies of odors, visibility, and the behavioral effects produced by air pollution. Eleven additional industry cost studies will be initiated in fiscal year 1972. Additional work will be conducted to determine the health effects of air pollution. A cooperative effort between DOT, EPA, and HUD on urban and transportation planning will be underway in fiscal year 1972.

Funds (in millions of dollars) expended by EPA on evaluation of effects during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
8.60	8.70	8.45

National Science Foundation

As a part of the NSF General Ecology program, a pilot study is underway to determine the levels of SO_x and O_3 that produce observable changes in the photosynthetic rate of white pine, chosen because of its high sensitivity to ozone. NSF is also studying the effects of air pollution on weather. Of particular interest is a project in the highly polluted St. Louis, Mo. area, where the climatic effects of air pollution are being analyzed through support from the National Center for Atmospheric Research (NCAR) and the program Research Applied to National Needs (RANN).

Funds (in millions of dollars) expended by NSF on evaluation of effects during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
2.24	2.40	2.71

Tennessee Valley Authority

TVA is participating financially with Edison Electric Institute, Bituminous Coal Research, and others on a research project directed toward obtaining fundamental knowledge of the physiological effects of sulfur dioxide and related steam plant pollutants on experimental animals.

Funds (in millions of dollars) expended by TVA for research into the effects of air pollution during

fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.02	0.02	0.02

MEASURING AND MONITORING

Atomic Energy Commission

The AEC conducts a worldwide air and precipitation sampling system, and in cooperation with DOD, conducts a high altitude sampling program for fallout radioactivity. The data are needed in the development of improved general atmospheric circulation and long range fallout models. Measurements of sulfates, water vapor, ozone, HNO_3, ammonia, etc., have been recently added to the high atmosphere program, and stable metals to the surface program.[7]

Department of Commerce

The current program of DOC research directly related to measuring and monitoring techniques for air pollutants includes a number of projects related to particulates. For example, a project is being conducted to develop a simple method for determining size distribution of airborne particles by light scattering. Other research is aimed at developing standard reference samples for airborne particulates. Studies of the photochemical reactions of SO_2, singlet O_2, and O_3, as well as the thermodynamic properties of air mixtures, are also underway.

Future DOC research in this area will include a greater number of projects leading to new standard reference materials (SRM's) to be certified and issued by the National Bureau of Standards for on-site instrument calibration by the user. Other research on SRM's will be stepped up in anticipation of control programs for aldehydes, mercaptans, fluorides, polynuclear aromatics, trace metals, and heavy metals. New projects also will be initiated on atmospheric corrosion of metals and on the use of the corrosion fine of metal wires as a means of measuring pollutant concentrations rapidly and cheaply.

Also reported in this section are some 40 DOC projects in analytical chemistry, humidity measurement, and measurements of properties of gases and rates of reaction, which are indirectly related to air pollution control in that they represent contributions to the state of the art in the fields they represent. These projects account for $4.4 million of the total funds reported for fiscal years 1969–71.

Funds (in millions of dollars) expended by DOC on measuring and monitoring during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
1.65	1.74	1.84

Department of Defense

DOD conducts air filtration studies indirectly related to the measuring and monitoring of air pollution. For example, kits and devices are developed in the chemical defense program to detect the presence of chemical contamination of the air.

Funds (in millions of dollars) expended by DOD for measuring and monitoring during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.02	0.03	0.09

Department of the Interior

DOI's Bureau of Mines is conducting fundamental studies on the chemical and physical properties of coal to provide support data for applied R. & D. programs. Spectroscopic, X-ray, microscopic, and petrographic studies are being conducted to gain additional information about the nature of coal and coal products.

To promote more efficient burning of coal in power generation, newly developed techniques are being used to study the minerals contained in coal and the transformations that these minerals undergo during combustion. A nuclear device employing Californium-252 is being developed to monitor the sulfur content in a moving stream of coal leaving the preparation plant. Research has also included the study of over 160 different world coals that were ashed in an oxygen plasma and the resulting unaltered mineral residues analyzed for their individual mineral constituents.

Future research in this area will include further chemical and physical studies of coal to obtain more information on the nature of coal and how it behaves during various preparation and utilization processes. Spectroscopic, microscopic, X-ray, and other analytical techniques will be employed.

The Bureau also conducts research related to measuring and monitoring gases and dust in mines.

[7] Funding for this AEC program has been included in the totals listed in the special studies—radiation section of this report.

Portable devices are being developed for measuring noxious gases and float dust in mines. Handheld methane meters, of the required accuracy and precision, have been found practical. Other quick-recording devices for noxious gases are in the laboratory stage of development. Devices developed in this program must be inexpensive, safe to operate in potentially hazardous atmospheres, and capable of providing rapid and accurate readings. Future plans include the construction of prototypes of the devices. Evaluations are to be made in mines to determine performance characteristics.

Funds (in millions of dollars) expended by DOI on measuring and monitoring during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.40	0.80	1.40

Department of Transportation

Research is being conducted by DOT's Federal Highway Administration to gain a fuller knowledge and understanding of the air pollution problem and its scope for various highway and highway-related situations. An example is a study of highway tunnel ventilation in which pollutants are being measured to determine conformity with analytical models, to establish tolerable limits for satisfactory use, and to develop means of attaining acceptable limits with consideration of purification and recirculation of the air in the tunnels instead of expulsion into the surrounding atmosphere.

Funds (in millions of dollars) expended by DOT on measuring and monitoring during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0	0.15	0.33

Environmental Protection Agency

EPA's research in this area was reported by the Air Pollution Control Office. The three programs in this section can be classified as relating to ambient air quality, instrumentation studies, and mobile source standards.

The objective of the EPA research program related to measurement of ambient air quality is to assess the air quality of the Nation in terms of specific air pollutants and their sources through a combined effort of Federal, State, and local surveillance networks and a federally coordinated information service.

In fiscal year 1971, for example, a project is being conducted to determine the ambient concentrations of newly defined pollutants. Studies are also being made to enable the measuring of ambient levels of pollutants under special conditions such as those found around smelters, near airport terminals, or in canyon situations.

The objective of the instrumentation studies program is to assure the timely availability of the instrumentation and analytical techniques required in support of Federal, State, and local programs for all major pollutants.

Current programs include research on several advanced instruments and methods, such as atomic emission fluorescence, infrared devices, spectroscopy, particle light scattering, and laser absorption for monitoring acetylene, ethylene, allergens, ozone, sulfur oxides, carbon monoxide, nitrogen oxides, beryllium, chlorine, hydrogen chloride, asbestos, mercury, and additional trace metals.

Improved techniques are being provided for assessing urban atmospheric conditions by completing data reduction techniques for thermasonde use, assessing atmospheric thermal stability, and demonstrating an acoustic doppler radar system for remote measurement of wind and turbulence.

In fiscal year 1971, instruments will be field-tested for ambient air monitoring of ozone, particulates, H_2S, gaseous and total fluorides, total sulfur, CO, methane, asbestos, and pesticides. The necessary design and performance criteria are being developed for prototype field instruments to measure remotely stack emissions of particulates, nitrogen oxides, and sulfur oxides. Sensors and monitors will be evaluated for source measurement of sulfur dioxides, nitrogen oxides, particulates, and fluorides.

The comparative testing of available stationary source monitors for CO, CO_2, O_2, and sulfur oxides and manual methods for sampling stationary source emissions for particulates and SO_x will be completed in fiscal year 1971. Technical assistance also will be provided for the application of a craft mill sulfur gas analyzer.

A single multichannel analyzer to analyze exhaust gas for carbon monoxide, carbon dioxide, hydrocarbons, and nitrogen oxides is being constructed. Sampling and analysis techniques for particulate emissions in auto exhausts, techniques for reactivity determination, and more sensitive techniques for nitrogen oxides, carbon monoxide, hydrocarbons, and particulates in exhausts from power plants are

being surveyed and evaluated. Studies to develop chromatographic methods for rapid analysis of benzo-a-pyrene and 6 to 12 polynuclear arenes are also underway.

Future EPA research in this area will be aimed at further developing the instruments designed in fiscal year 1971, and at least eight other techniques for high priority pollutants named in national ambient air quality standards and national emission standards. The feasibility of measuring total atmospheric pollution by using ground and coorbiting satellite-borne electromagnetic energy receivers and sources also will be demonstrated. An operational prototype acoustic doppler system will be developed, and the construction of a second generation radiometric thermasonde will be initiated. Prototype field instruments for remote measurement of sulfur dioxide, particulate, and nitric oxide from stationary sources will be developed.

The objectives of research related to mobile source standards and procedures are applicable to all new motor vehicles for the 1972 to 1975–76 model years and to have fully implemented compliance, surveillance, and inspection systems that will insure that all motor vehicles produced, domestic and foreign, meet applicable standards at the time of production and maintain acceptable emission performance levels through the entire life of the vehicle.

Current research is aimed at identifying and quantifying particulate emissions originating from lead and unlead fuels, brake linings, clutches, and other nonmetallic materials. Gaseous emissions from light aircraft are being measured and odor-causing species in diesel exhausts are being identified. Other research aims to characterize the physical nature of particulate emissions from commercial aircraft.

Future EPA programs in the mobile source area relate to the development of methods for analyzing particulate emissions from lead and unleaded fuels. Major pollutant measurements on six classes of off-highway vehicles and the identification of odor-causing species in gas turbine engine fuel also will be completed.

In fiscal year 1972, the following programs will be developed: A project to collect and evaluate information on driving patterns in six metropolitan regions, a mass emissions test procedure applicable to gasoline-powered heavy-duty engines, an improved evaporative test procedure for hydrocarbons, and procedures for inspection testing by State agencies of light-duty vehicles.

Funds (in millions of dollars) expended by EPA on measuring and monitoring during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
2.80	5.60	7.74

National Aeronautics and Space Administration

NASA's research in this area is mostly related to the development of instrumentation. For example, a portable CO sensor using infrared dispersion and a spectrometer is being developed. Also, a mass spectrometer has been developed to measure gas samples containing H_2, N_2, total hydrocarbons, and Freon.[8] Another study to develop a hybrid sensor, which consists of a mass spectrometer and selective columns from a gas chromatograph, is underway. NASA is also developing an inexpensive analysis and identification system for particulates. This system is to be used in conjunction with an existing network of 20 air-monitoring stations in Cleveland, Ohio. Instruments utilizing optical lidars and lasers are being developed.

Funds (in millions of dollars) expended by NASA for measuring and monitoring during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0.20	0.17	0.62

National Science Foundation

NSF research in this category pertains to the contribution of solid waste to air pollution and includes fundamental combustion studies of solids and gases and photochemical and gaseous chemical reactions; movement of small particles in flow fields; studies of electrostatic precipitation of solids from gaseous streams, and development of analytical techniques for trace element contaminants. For example, reactions of carbon monoxide in a competitive flame system are being investigated. The thermal degradation of cellulosic materials is being studied to determine free radical intermediates formed during controlled pyrolysis of carbohydrates.

Techniques for studying the kinetics and chemistry of solid decompositions at surfaces at very low decomposition rates are being developed. Research related to the development of analytical methods includes the use of atomic absorption spectroscopy.

NSF research on measuring and monitoring methods also includes research applied to national needs

[8] Mention of trade names does not imply recommendation or endorsement by the Federal Government over others not mentioned.

(RANN) studies of the movement of all forms of lead through the environment and the effects of mercury on the environment. Another long-range research program is underway to investigate the content and variability of CO_2 in the atmosphere. Other gases, such as H_2, CH_4, and CO, also are being measured. A mechanism for the formation of the stratospheric sulfate aerosol is being developed.

Funds (in millions of dollars) expended by NSF for measuring and monitoring during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0.84	1.38	1.86

PREVENTION AND CONTROL

Corps of Engineers

The CE program in prevention and control includes R. & D. aimed at designing and constructing an incinerator that will be used to burn the drift collected in New York harbor. The project includes the design and fabrication of an overfire air pit-type incinerator to meet air pollution abatement standards and requirements.

Funds (in millions of dollars) expended for prevention and control by CE during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
1.31	0.25	0.04

Department of Agriculture

USDA has reported a major program to avoid or minimize air contamination by pesticides. More definitive methods of application, and improved, low-volatile formulations of currently available pesticides are being investigated. As a result of this program, low-volatile herbicides have been produced. Application of pesticides by brushes, as a foam formulation, or by special equipment that catches and returns runoff to the spray tank have also been established as usable.

Research to determine the effectiveness of burning crop residues as a method to control plant diseases, insects, and weeds is in progress. To reduce the need for burning crop residues, highly selective chemicals for use as defoliants, desiccants, and growth modifiers have been developed. Future work will continue to stress the development of methods for pest control other than burning of crop residues.

Other USDA programs are attempting to identify and control gaseous components from animal wastes that cause odor.

A USDA program to determine the relationship of soil erosion to air pollution also has been reported. The result should facilitate prediction of potential rates of erosion by wind for varying soil, vegetative cover, field width, and barrier design conditions.

An extensive USDA program to develop controls for the prevention or reduction of diseases that damage or destroy shelterbelts is in progress. The objective of this program is to protect and maintain adequate shelterbelts and thereby reduce air pollution by soil particles. Research includes a variety of projects to control forest diseases that damage shelterbelts and to reduce growth loss and tree mortality resulting from damage by insects. Other projects to develop better strains of shelterbelt trees through genetics and to maximize the effectiveness of shelterbelts in reducing wind erosion and protecting crops are in progress.

The USDA has also reported an R. & D. program to produce straight defect-free trees to reduce waste in primary manufacture. Related USDA projects in forest products utilization are attempting to eliminate smoke from wood burners and odors from pulp mills. Increased uses of pulping wastes and improved pulping methods are being sought to reduce the burning of wood wastes and the odors from pulping wastes. Potential nonpolluting pulping reactions based on oxygen rather than sulfur have been screened. Data required for the use of wood residues as ruminant roughage have been developed.

Funds (in millions of dollars) expended by USDA for prevention and control during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
2.59	3.07	3.25

Department of Defense

The Department of the Air Force conducts research to characterize and quantitate the combustion products from incinerating solid waste including plastics. The Air Force also conducts various other projects indirectly related to preventing air pollution. For example, the primary concern of the Air Force with respect to jet engine exhaust smoke has been its relation to enemy detection of smoke trails. In 1966 a development action was initiated for the F–4 aircraft. Research efforts to reduce the F–4 smoke from the General Electric J79–15/17 engine

appear to have been successful in laboratory tests. Combustion system design techniques to increase the combustion efficiency of turbine engines at low power settings are being investigated. Other investigations to reduce exhaust emission include (1) fundamental study with experimentation to determine whether fuel modification, such as introduction of catalysts and absorbers, is feasible for reducing the level of NO_x emissions from turbine engines and (2) the determination of the optimum concentration of proposed fuel additives. An integral part of reducing emissions is the development of a system with minimum human involvement for the direct, real time measurement of CO, CO_2, NO_x, C_xH_y from turbine engines.

The Department of the Army is developing lighter weight and higher performance engines for vehicles, aircraft, and stationary power units. Efforts to improve efficiency have also resulted in more complete combustion and reduced exhaust emissions. Prototypes have been completed and tested on vehicle engines using a new type of combustion chamber, which is a hybrid between spark- and diesel-type engines. The continuous combustion of a swirling ignition process has been shown to reduce exhaust emissions to meet 1975 standards set by EPA. Studies are also underway to improve turbines to increase efficiency and decrease emissions. Visible smoke was virtually eliminated from an aircraft turbine engine, and methods for analyzing the chemical constituents of engine exhausts were developed.

The primary aim of another Army R. & D. program is to improve liquid hydrocarbon fuels so as to reduce undesirable emissions.

Techniques are also being developed by the Army to reduce emission of NO_x, SO_2, and particulate matter from military power plants. Good results have been obtained using a water spray scrubbing technique. The resulting waste water is processed through sewage treatment plants. Short-range plans are for completing work on reduction of NO_x and SO_2. Long-range plans depend on the nature and scope of R. & D. efforts by industry and other Federal agencies.

The Department of the Army also conducts research indirectly related to air pollution control. For example, in order to reduce the chances for enemy detection, the Army is developing propellants for missiles, rockets, and artillery projectiles that generate less smoke than present propellants. A laboratory system to simulate gun propellant smoke and flash was recently completed and is now being tested. Contaminant content of propellant exhausts is being reduced to improve conditions for electrical and optical sensors on missiles and rockets.

The Army is also developing fuel cells and high energy density batteries to improve efficiency of generators and to provide energy sources with higher reliability and higher ratios of energy to weight and energy to volume. Fuel cells that indirectly use hydrocarbons have been developed at the 0.5- and 1.5-kilowatt levels. The hydrocarbons are thermally cracked to produce hydrogen for use in the fuel cells. Significant progress is also being made on metal-air, organic electrolyte, and improved energy density batteries. Short-range plans are to continue efforts at approximately the present level. Long-range plans are to use hydrocarbons directly in inexpensive fuel cell systems.

The Department of the Navy has reported research aimed at preventing and controlling air pollution from aircraft. One Navy program is investigating the feasibility of using modified fuels to reduce smoke from airplanes. Various burners for J79, TF41, and TF30 engines are being tested. The Navy also reported a project to develop a water spray device as an economical method for reducing smoke at firefighting schools. Incinerators for classified materials were developed.

Funds (in millions of dollars) expended by DOD for prevention and control during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
8.24	7.30	7.43

Department of the Interior

The DOI programs reported in this section are exclusively those of the Bureau of Mines. Many of the activities of DOI in this area are directly coordinated with EPA through interagency transfer of funds.

A program to remove pyritic sulfur from coal is in progress. Various approaches being investigated to remove pyrite include the use of a centrifuge to separate pyrite from coal in a water medium and selective grinding, followed by air classification and electrostatic methods of removal. A novel technique being explored takes advantage of the wide differences in dielectric properties of coal and pyrite to selectively heat pyrite at microwave frequencies and thus enhances its susceptibility to conventional magnetic separation. Another project studies ion-exchange methods for removing deleterious minerals from lignite before combustion. Future work will be

continued to improve these removal techniques and tests will be extended to other coals.

Research on removal of SO_x and NO_x from stack gases is also pursued. In SO_x control research, a laboratory investigation of the Bureau's ammonia injection process has been completed. Research involving SO_x sorption by copper oxide impregnated into an alumina support has been conducted. Investigations also have been made of the effectiveness of low-cost materials for SO_x control in stack gases, such as red mud, nahcolite, and trona. Research on NO_x removal has been carried out using several catalysts including NiO, which has been found to be the most effective.

Further research on the ammonia injection process and additional study of the copper oxide-alumina sorbent removal of SO_x are planned. Research will be continued on the mechanism and kinetics of SO_x or NO_x sorption or both on red muds and trona. An index of ores and waste products will be compiled, based on their relative potentials for SO_x removal. A survey of metal oxide catalysts for treating NO_x will be continued.

DOI is also conducting a program to reduce toxic emissions from internal combustion engines. Currently the work is being expanded to improve the safety of diesel engines operating in underground mines. The aspects being examined are toxicity, explosion, and fire potential of the fuel, and the possibility of igniting methane by incandescent exhaust products. The objectives of future research on internal combustion engines are to recommend fuel formulations, operating parameters, and auxiliary devices that will reduce undesirable emissions to tolerable levels.

DOI is also conducting studies on the availability of fuels that meet air pollution control requirements. Studies have been conducted on the availability of coal. Investigations of petroleum and natural gas resources have determined the factors that affect ultimate recovery and supply, enabling forecasts to be made of future petroleum and natural gas availability. Research also has been conducted to encourage production of fuels that involve less pollution of the atmosphere than coal. Future plans include appraisals of coal-producing areas where coal is mined underground. Costs of the development and utilization of petroleum and natural gas resources will be estimated.

Of the $18.4-million R. & D. program reported by DOI in this section, the Department has indicated that $12.9 million could be considered indirectly related to pollution control but relevant to air quality. The following summaries include those projects so designated.

A program is in progress to develop chemical processes alternative to roasting of sulfur ores. Another program aims to recover elemental sulfur from typical smelter gases. The process that has received major attention involves selective absorption of SO_2 in a solution of an organic acid and its salt and subsequent reduction with hydrogen sulfide to form elemental sulfur.

A major DOI program on the gasification and liquefaction of coal is in progress. Gasification work is directed chiefly toward development and demonstration of a process to produce a synthesis gas suitable for catalytic upgrading into pipeline gas. A hydrogasification process to produce low-sulfur char, as well as pipeline gas, is being developed. A fixed-bed pressure gasifier, using caking coals without pretreatment, was operated with various types of coals.

Research is also underway to develop more efficient utilization methods for mineral resources. Magnetohydrodynamics (MHD), for example, offers a potential means to generate electrical power more efficiently than in conventional powerplants. In the MHD combustion tests, virtually complete removal of sulfur oxides in the combustion gas has been accomplished and 99 percent of the seed material regenerated. A vortex MHD generator is being operated to show its efficiency and a two-stage combustor program is just getting underway.

The burning characteristics of bituminous coal, chars, and lignites are being studied in test furnaces to determine the effect of variations in primary, secondary, and tertiary air combustion efficiency and formation of SO_2, SO_3, NO_x, and organic acids when burning coals of various ranks. Research is being conducted on development and application of new knowledge on combustion processes that cause deposition and corrosion on boiler heat transfer surfaces, resulting in costly shutdown of power-generating units.

The Bureau of Mines is also conducting research on coal incineration, pyrolysis, and utilization of solid wastes from combustion. Among objectives of this work are the utilization of byproduct wastes from mining, treatment of coal to remove pyrites and other sulfur-bearing constituents, and development of alternate methods of combustion so as to reduce formation of fly ash and other solid waste residues. Studies on utilization of fly ash and strip spoil have shown results. Chemical and physical studies have yielded information on the nature of

coal and the bearing that this information has on preparation and utilization processes.

Solid waste resources surveys are in progress. The program includes identification of waste-disposal problems, development of guidelines for proper disposal of wastes, identification of mineral resources available from present and future accumulations of solid wastes and development of methods for recovering useful materials from such wastes. For example, a survey that established the magnitude and kinds of dusts generated has been completed of the iron and steel industry. Future studies will include inventories of mineral wastes. Secondary sources of copper throughout the Nation also will be studied to determine the potential for utilizing more of the copper currently being discarded as scrap.

Funds (in millions of dollars) expended by DOI for prevention and control during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
4.98	5.58	7.88

Department of Transportation

DOT is conducting R. & D. to reduce air pollution from aircraft. Other projects to develop low-pollution bus engines and to test devices for reducing exhaust emissions from buses are in progress. Two types of steam engines are being developed in this program.

Various DOT projects that would contribute indirectly to air pollution control also have been reported. Of the $12.7 million research program described in this section, $10.2 million has been classified as indirectly related. These activities include developing an electrically propelled rail vehicle and designing and relocating rail yards. A considerable research effort is also being conducted to investigate tunneling techniques for subsurface transport systems. DOT is also funding the development of an environmental control handbook for engineering and design standards to improve underground rapid rail systems.

Funds (in millions of dollars) by DOT for prevention and control during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
2.60	6.23	3.89

Environmental Protection Agency

The $33.9 million research program in prevention and control technology reported by EPA's Office of Air Programs for fiscal year 1971 represents the largest single dollar investment of any program included in this report.

One of the major EPA efforts is the Advanced Automotive Power Systems Program (AAPSP) which is designed to stimulate the automotive industry to independently develop the most promising candidate systems, while the Government continues a Federal R. & D. program through to demonstration of selected systems not actively pursued by industry.

The leading candidate is the gas turbine. The industry has considerable past experience with this system and is attempting now to solve the technical problems that have limited its application to the automobile. These problems include high NO_x, poor fuel economy, and high cost to produce. For this candidate, the AAPSP will devote considerably increased research effort to solving these problems. For example, multiple and alternate technical approaches to solving the high NO_x problem will be made to industry through the competitive contract award mechanism. Achievement of practical solutions to the technical problem hopefully will stimulate the auto industry companies to "pick up" this technology and apply it in their own ways to automobile designs. Thus, properly applied stimulation in this manner will not require that the Government AAPSP program assemble and demonstrate the gas turbine as a system to achieve program goals.

To better insure success of the AAPSP, two engine systems new to the program will be added in fiscal year 1972: The stratified charge engine and the diesel engine. Recent developments have clearly indicated that these systems offer the potential of achieving virtually pollution-free emissions and replacing the conventional internal combustion engine. Early demonstrations of newly developed concepts for these engines will be made during calendar year 1971 and decisions then will be made whether to proceed with further development under Government funding in the program.

An extensive conventional mobile source program is also in progress. The objective is to minimize pollution from conventional motor vehicle and off-highway engines by proving the feasibility of emission control devices under development in the private sector, evaluating alternative fuels and fuel additive systems, and conducting supplemental applied research.

Engines and accessories modifications are being studied. These include continuation of two experimental programs designed to establish high efficiency removal devices for particulates; verification of car-

buretor design requirements for reduced emissions; determination of best materials for construction and design configuration of a thermal reactor for hydrocarbon and carbon monoxide removal; selection of a prime nitrogen oxides control system candidate for experimental evaluation applicable to internal combustion and diesel power plants; continuation of emissions performance studies for a stratified charge engine; and continuation of a coordinated effort with FAA in gaseous emission controls for aircraft.

To develop control techniques, the following will be accomplished in fiscal year 1971:

- Evaluation of studies on new control techniques, including fuel composition changes.
- Thorough dynamometer and road testing to determine exhaust emission, performance, and economy.
- The rendering of technical assistance to other Federal agencies.
- The fleet-testing of control devices for diesel odor and smoke control.

Efforts in this area will be expanded in fiscal year 1972 to derive experimental data on low-cost retro-fit devices for existing civilian and military vehicles and off-highway equipment. Testing emphasis will shift to techniques with apparent capability of surpassing 1975 standards, and a study on effects of fuels composition on vehicle emission performance will be completed.

The development of control technology for stationary sources of air pollution represents another major EPA effort. The objective of this program is to define control technology research needs with respect to significant industries, major pollutants, and classes of control devices, and to maintain aggressive research, development, and demonstration programs to insure an adequate control technology base for standards implementation. The financial and technical capacity of private industry will be drawn upon in this effort to the fullest extent possible.

To control sulfur oxides, a major program includes the demonstration and testing of the limestone processes-dry limestone injection, limestone wet scrubbing, limestone modified fly ash utilization, and the complementary R. & D. programs.

The detailed construction, design, and test program development for a prototype coal-cleaning plant is to be completed in fiscal year 1971. Different techniques for removing pyritic sulfur and ash from coal are being examined. Sulfur recovery from coal-cleaning wastes is being studied. An investigation to determine washability characteristics of the principal U.S. coal beds is continuing. This program is coordinated directly with DOI activities by interagency transfer of funds.

Two cosponsored demonstration plants for the removal of sulfur oxides, the Monsanto Cat-Ox and Magnesium Oxide Wet Scrubbing, will reach the advanced stages of construction in fiscal year 1971. A smokeless coke oven charging demonstration project cosponsored with the American Iron and Steel Institute and cosponsored contract studies with the wood pulping industry are beginning in fiscal year 1971. A system to demonstrate the feasibility of firing refuse mixed with powdered coal at an electric utility station is being designed.

Planning studies will be initiated in fiscal year 1971 for the paint and varnish and secondary aluminum smelting industries. The annual updating of the R. & D. plans for sulfur oxides and nitrogen oxides and the R. & D. planning study for particulates will be published in fiscal year 1971. An R. & D. planning study for lead, hydrocarbons, and fluorides will be initiated. A special study to develop a supply-demand model for sulfur is in progress.

Other current projects include the development of authoritative handbooks for fabric filters, electrostatic precipitators, and wet scrubbers. Studies and evaluation are continuing on afterburners and package sorbers, odor control, and incineration. Several combustion techniques, including catalysis, fluidized bed, flue gas recirculation, staged combustion, fuel modulation, and standard burner modification, are being investigated.

A feasibility study to determine the minimum particle size resolution of the holographic technique and laboratory methods developed for monitoring selected species in the alkaline-metal scrubbing process will be completed in fiscal year 1971. Studies of the characteristics and control of nitrogen oxides, coal desulfurization, and gas-cleaning processes are underway. Pilot tests are continuing on the aqueous scrubbing, regenerable char, absorption process recovery system. The technical feasibility of fluidized bed combustors to control sulfur oxides and nitrogen oxides from fossil-fuel burning industrial and utility boilers is being evaluated.

Data acquisition and analysis will be completed in fiscal year 1971 for the Large Power Plant Effluent Study (LAPPES), Keystone Plant, to evaluate the effectiveness of natural precipitation for power plant plume washout and resulting ground-level effects.

In fiscal year 1972, further evaluation and studies will continue on control devices. Projects to characterize fabric filter bag structure and operating parameters will be completed. Two studies to up-

grade electrostatic precipitator performance will be concluded. Implementation of R. & D. plans for wet scrubbers will be started. Handbooks for afterburners and package sorbers will be provided. Laboratory testing of several scrubbers systems for odor control will be concluded and prototype designs for on-site studies will be complete. Design principles for incinerator overfire mixing will be confirmed.

Research in the area of catalysis and modified combustion kinetics will be extended in fiscal year 1972. Techniques showing promise will be evaluated for application to larger scale commercial and industrial heating units. Future work in sampling and analysis will include investigation of the capability of the holographic technique for fine particulates, provision for analytical support to major flue gas-cleaning projects underway, and completion of the characterization of particulate air pollutants emitted from fossil-fuel combustion.

Field trials of modified combustion techniques for control of nitrogen oxides in utility size boilers will be underway in fiscal year 1972. A sulfur behavior study and a molten iron/coal combustion feasibility study will be concluded. A sodium-based sorbent process evaluation will be completed. Pilot testing of aqueous ammonia scrubbers will be finished. The construction of a regeneration system pilot plant will be initiated. An additional flue gas-cleaning pilot study and three fossil-fuel conversion pilot investigations will be initiated.

Future research also will include data acquisition from two powerplants in the LAPPES project to study the transport and diffusion of plumes from tall stacks in mountainous terrain and to determine climatological data for plant siting. Demonstration and testing of the limestone processes will continue in fiscal year 1972. The dry limestone test program will be completed, and a report issued. A 2-year limestone wet-scrubbing test program at the TVA site and the 12-month test program at Key West will be initiated.

In fiscal year 1972, the construction of a prototype coal-cleaning plant will be completed and test program operations will begin. The examination of two physical methods for removing pyritic sulfur and ash will be completed. A feasibility determination on a combustor and sulfur recovery process from coal-cleaning waste will be concluded. Investigations will continue to determine washability characteristics of the principal U.S. coal beds. Experimental test programs will be underway at the two flue gas demonstration plants. The coke oven charging demonstration will be completed. Four to six new projects under cost-sharing arrangements with industry will be initiated. The construction phase will be completed and test operations begun for a demonstration grant on the feasibility of firing refuse mixed with powdered coal at an electric utility station.

A major contributing factor to air pollution is the problem of reducing solid waste by open burning or incineration. The EPA Office of Solid Waste Management, therefore, has reported an extensive program to improve incinerator technology to meet air pollution standards, increase volume reduction, and lower incineration costs.

Vortex and high temperature incinerators have been evaluated. A small mechanically stoked, rotary grate incinerator for communities with less than 25,000 population is being demonstrated.

Future work in this area is expected to receive increased emphasis. A prototype pyrolysis unit may be demonstrated and evaluated. A fluid bed combustor, which may provide more complete combustion and lower costs, is presently in a development stage.

Funds (in millions of dollars) expended by EPA for prevention and control during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
17.77	26.48	34.26

General Services Administration

The GSA dual-fuel program includes research and testing of gaseous fuels for automobiles that will make possible low emission operation. This work incorporates the conversion of conventional vehicles to a system in which compressed natural gas, liquid natural gas, or liquid petroleum gas can be used as a substitute for gasoline.

The program objective is to test and evaluate the economic feasibility, for commercial fleet operation, of the use of natural gas or liquid petroleum gas as alternate fuels that will meet the 1975 automotive vehicle emission standards.

Funds (in millions of dollars) expended for prevention and control by GSA during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0	0.11	2.08

National Aeronautics and Space Administration

NASA is conducting R. & D. aimed at preventing and controlling aircraft emissions. The present trend

of advanced engines is to high temperatures and high pressure ratios. Smoking tendency and nitrous oxide exhaust emissions are worsened by an increase in pressure. A major part of the NASA experimental work, therefore, is conducted at high pressures, but the results are applicable to current engines that operate at lower pressures. Experimental gas turbine combustors are being tested to evaluate their overall performance and their smoking tendency. Various design features are being studied, which include variations in air-entry ports and variations in the fuel injection system. A study of the emission problems of the typical turbojet/turbofan engine at idle will be funded in fiscal year 1971.

Other NASA mobile source control R. & D. concerns automotive emissions. Thermal reactors for emission control are being tested. A device that would permit more accurate control of fuel/air ration in internal combustion engines is being developed.

NASA R. & D. related to controlling stationary sources includes a laboratory investigation of the effectiveness of a magnesium dioxide and lithium carbonate bed for removing sulfur oxides, chlorine, and hydrogen halides.

Funds (in millions of dollars) expended by NASA for prevention and control during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0.15	0.27	0.92

National Science Foundation

Within the NSF chemistry program, research is in progress to find new oxidizing agents that can react by an oxygen atom transfer mechanism, resulting in the development of new oxidizing agents for hydrocarbons. Other studies include a development of improved methods for determining the sulfuric acid aerosol and sulfate particulates. The principal effort is directed toward the quantitative reduction of SO_3 and SO_2. Some of these studies have the potential for affording new chemical means of controlling such oxides in an air environment through the ability of metal complexes to promote chemical reactions necessary for the conversion of oxides to less noxious materials. Further studies are in progress on the mechanism of ozonolysis.

Funds (in millions of dollars) expended by NSF for prevention and control during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0.45	0.32	0.56

Tennessee Valley Authority

In addition to air quality studies leading to operational control of coal-fired power plants TVA is conducting research to recover sulfur in useful form from power plant stack gases.

Funds (in millions of dollars) expended by TVA for research related to prevention and control during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0.18	0.17	0.17

TRANSPORT AND FATE

Atomic Energy Commission

The transport and fate effort of the AEC covers a broad range of research in the atmosphere, with a focus on processes that will allow improved understanding of radioactivity, and assists in the AEC's mission of assessing the biological implications of radiation.

The AEC has conducted a substantial effort over the years aimed at describing diffusion and plume rise to modest distances from a source of radioactive substances. This effort is being shifted to intermediate and large distances in order to address the consequences of very small concentrations of pollutants to large populations, and over long periods of time. These populations reside in cities, and with nuclear power systems being sited close to major cities, the AEC effort includes research on diffusion from point sources over changing rural-urban terrain.

The ability to estimate dose contributions through food chains depends on understanding the atmosphere—biosphere interface. The net gain or loss of nutrients, trace elements, and toxic materials in an ecosystem, for instance, ties in closely to the behavior of analogous radioactivity. Consequently, the studies include programs in cleansing of air by precipitation and dry deposition, and resuspension back into the air of materials deposited earlier.[9]

Department of Transportation

Research is being conducted to better enable DOT to issue regulations that effectively reduce aircraft pollution and to insure that the standards are at the same time technically sound and economically rea-

[9] Funding for this AEC program has been included in the totals listed for the AEC in the special studies—radiation section of this report.

sonable. Projects include analysis of the pollutant effects of aircraft ground operations, engine emission dissipation rates, and the effect of engine emissions at altitude.

Funds (in millions of dollars) expended by DOT for transport and fate during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0	0.05	0.35

Environmental Protection Agency

EPA research on atmospheric processes was reported by the Air Pollution Control Office. The objective of this research is to delineate important physical and chemical atmospheric processes altered by the major air pollutants.

Research in this area includes validation of available urban diffusion models. Other projects seek to determine the relationship between air pollution and the earth's radiation budget. Field and laboratory studies are also conducted on atmospheric smog to evaluate the photochemical reactivity of pollutants. The fate of carbon monoxide arising from combustion sources, as well as the interaction and fate of particulate pollutants in the atmosphere is also being studied.

Future research in this area will be aimed at better defining the photochemical reactivity of pollutants in the urban and rural atmosphere. Projects to obtain information on predicting atmospheric levels of air pollutants and the contribution of non-technologically produced carbon monoxide to air pollution levels will also be undertaken. The sulfur dioxide-particulate relationship in the atmosphere will be studied, and the aerosols formed in certain photo-oxidative systems will be characterized.

Funds (in millions of dollars) expended by EPA on transport and fate during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
4.80	4.70	4.20

National Aeronautics and Space Administration

NASA's research in this area includes a variety of projects related to the dispersion and chemical transformation of air pollutants. For example, one project seeks to determine the mechanisms by which ultraviolet radiation transforms nitrogen oxides into smog in the presence of hydrocarbons. The objective of another project is to investigate the chemical kinetics of the dispersion of pollutants with primary emphasis on hydrocarbons. Investigations are also underway to determine the kinetics of smoke and nitric oxide formation under conditions found in aircraft gas turbine combustion systems and to determine the dispersion and interaction of pollutants from airborne and ground sources in urban areas.

Funds (in millions of dollars) expended by NASA for transport and fate during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0.10	0.12	0.16

National Science Foundation

NSF conducts research related to the transport and fate of a variety of air pollutants. In the pesticides area, the photolytic decomposition of chlorinated hydrocarbons is being studied. Additional work will attempt to analyze the amount and fate of DDT carried by air currents from the area of application.

Further, the NSF Atmospheric Science program is supporting analytical studies of air samples from Antarctica, New Zealand, and Australia. Particulate and gaseous samples of halogens (I, Br, Cl) are being collected to study the effect of a large land mass on atmospheric gaseous halogen concentrations. This research may determine the north-south transport of air pollution to the extent that particulate matter of a northern hemisphere continental source is penetrating the Antarctic continent. Additional studies are being conducted to determine the contribution of African dust to the natural pollution of the atmosphere.

Funds (in millions of dollars) expended by NSF for transport and fate during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
1.06	1.67	1.76

Water Quality

Funding of water quality R. & D. for fiscal years 1969, 1970, and 1971 is reported in table 4 (p. 104).

AGRICULTURAL POLLUTION CONTROL TECHNOLOGY

Department of Agriculture

Plant residue wastes that are considered potential water pollutants are plant pathogens where waterborne organisms are found in water that is used for irrigation and that may serve to infect the soil or crop on which it is applied. Plant nutrients and dissolved organics that leach from plant residues and enter water courses through runoff are potential pollutants. These materials have a potential for stimulating the growth of algae and other aquatic plants, leading to acceleration of the eutrophication process. Increasing emphasis on environmental quality demands better control of potential pollution from crop and forest residues. Techniques have to be developed to minimize production of undesirable forest and crop residues. Increased beneficial utilization of these wastes are being explored. Emphasis is being given to control methods and the selection of plants and residues that may protect water quality indirectly through stabilization of highly erodible areas.

Liquid wastes from processing raw agricultural products represent a serious disposal problem, largely because of their biochemical oxygen demand (BOD). It is estimated that the pollution potential from this source expressed in terms of BOD is equivalent to that produced by a population of more than 168 million people. The presence of salts, other chemicals, and suspended solids in effluents compounds the problem.

Several possible solutions to the problem of disposing of these waste effluents are being studied. Land disposal is being explored as a means of preventing effluents from directly contaminating receiving streams. Applications by sprinkler and furrow irrigation are being considered from the standpoint of both beneficial crop production and simple disposal technique. Systems must be developed that consider the variability in amount and composition of the effluent produced, climatic conditions, and soil and crop factors.

Efforts are continuing to improve processing methodology that will facilitate disposal and minimize pollution hazards. Improved harvesting and processing practices need to be developed that will reduce wastes and pollution hazards. More emphasis is being placed on byproduct recovery and utilization as an economic benefit and a means of minimizing the waste disposal load.

Land disposal is a logical method for absorbing processing plant effluents and improving the quality of the resulting drainage water. Guidelines must be developed for specific effluents. These guidelines should take into consideration the effects of climatic conditions, hydrologic, and soil characteristics of the disposal area and vegetative requirements of that area.

In the United States an estimated 1.5 million tons of livestock wastes are produced annually. These wastes represent a potential water pollution problem because of their nutrient content, the occurrence and spread of pathogens, and the high BOD of these materials. Research directed at recycling these wastes into the soil-plant-water-animal system is needed. Waste disposal systems will have to be integrated into the overall planning and operational schemes for these large livestock systems. Concern over plant nutrients in water involves the acceleration of the eutrophication process and high nitrate concentrations in drinking water.

Current studies are evaluating the effects of land use, soil type, hydrologic conditions, climate, and soil management factors on the movement of plant nutrients in the environment. Mathematical models are being developed to predict nutrient movement and to provide information for developing more effective

control practices. Other programs are aimed at increasing fertilizer use efficiency. Watershed management practices are being developed to minimize nutrient losses by leaching and by runoff and erosion.

More information is needed to evaluate the contribution of chemical fertilizers in relation to natural sources. Processes involved in nutrient cycling in these areas need to be identified and quantified. More specific information is needed on factors that affect movement in soils and on chemical and biological transformations that take place before entering a water course. The major source of phosphorus from agriculture uses is absorbed on sediments. Greater definition of sediment-water equilibria is, therefore, needed to evaluate the potentially biologically active fraction. Effects of nutrients (soluble and undecomposed organic matter) on the eutrophication process must be evaluated.

Funds (in millions of dollars) expended by USDA for agriculture pollution control technology during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
5.22	6.71	6.62

Environmental Protection Agency

The objective of this program is the development and demonstration of technology for effective and economical control of pollution from agricultural activities, including forestry and logging operations, irrigation return flows, rural runoff, and animal feedlots. Short term goals include significant progress towards: Development and demonstration of effective pollution control from animal feedlots; development of methods for treatment and control of water quality degradation in irrigation return flows; exploration and development of methods to minimize runoff and pollution by agriculturally used fertilizers and pesticides; development and demonstration of crop management procedures to reduce runoff of agricultural chemicals and their effect on water quality; and demonstration of technology for complete elimination of pollution from animal feedlots through recycling of "waste" constituents.

Funds (in millions of dollars) expended by EPA for agricultural pollution control technology during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
1.37	2.44	2.47

Tennessee Valley Authority

TVA is conducting studies of the relationship of ertilizer use and water quality. Water quality and total runoff are now being measured on six watersheds. Nutrient losses in small streams and tile drains on agricultural lands are being studied with the University of Illinois.

Funds (in millions of dollars) expended by TVA for research related to agricultural pollution control technology during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.03	0.05	0.05

INDUSTRIAL POLLUTION CONTROL TECHNOLOGY

Department of Agriculture

Liquid wastes from food and industrial processing plants can be a serious pollution problem. Processing of animal and crop products produces liquid wastes, which have been estimated to equal the sewage load from 170 million people.

Research is underway on process changes that will minimize pollution, and on recovery and use of by-products. Recent laboratory and pilot plant results on "dry caustic" peeling of potatoes and other vegetables, on pickling brines recovery, and on cheese whey recovery have been extended to industrial scale by EPA demonstration grants, based on USDA research. Related work on poultry processing, soybean oil refining, tannery wastes, and cotton textile wastes is underway.

In the manufacture of pulp and paper from wood, the great variations in grades and the hygienic requirements of fiber products severely limit the recycle and reuse of process water, resulting in a substantial waste disposal problem. Nonpolluting chemical delignification systems are being explored that will be applicable to both pulping and bleaching processes and replace the sulfur and chlorine compounds used in existing processes. New knowledge of the basic chemical reaetions of the lignins and carbohydrates in wood is leading to further processing waste reduction.

Funds (in millions of dollars) expended by USDA for industrial pollution control technology during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
1.27	1.30	1.73

Environmental Protection Agency

The objective of this program is to develop and demonstrate economical technology for the complete

control of industrial waste discharges. Immediate goals are the demonstration of best available treatment and control systems for wastes from major industrial pollution sources, including the six large industries that use over 80 percent of all industrial water: metals, chemicals, pulp and paper, petroleum, coal, and food.

Demonstrations of new or improved systems for significantly reducing industrial waste have been conducted for metal plating shops, steel mills, food-processing plants, pulp and paper mills, organic chemical plants, and petroleum refineries.

This program includes development of:

- Waste treatment and source control techniques for difficult-to-control industrial wastes.
- Pretreatment techniques for safe discharge of industrial wastes into municipal sewer systems for joint treatment.
- High-efficiency treatment or control systems for all major industries.
- Closed-loop systems to eliminate industrial waste discharges through reduction of water use and renovation and reuse of waste waters and byproduct recovery.

Objectives of the program are:

- Demonstration of closed-loop systems to eliminate completely all industrial waste discharges.
- Development and demonstration of techniques for reuse of waste waters and recovery and reuse of "wastes" they now convey.

Funds (in millions of dollars) expended by EPA for industrial pollution control technology during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
9.01	7.36	6.00

MINING POLLUTION

Department of the Interior

The potential is being studied of desalting processes to treat acid mine drainage and to provide supplemental supplies of fresh water for municipal and industrial uses.

Funds (in millions of dollars) expended by DOI for mining pollution during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0	0.04	0.06

Environmental Protection Agency

Research is directed to the elimination of water pollution resulting from the extraction and preparation of minerals, including coal, copper, other metals, oil, phosphate, rocks, sand, and gravel.

Primary emphasis has been on definition of the mechanism of formation of acid coal mine discharges, evaluation and development of treatment processes for mine drainage, and evaluation of new methods for sealing or "plugging" mines to prevent discharge. The evaluation of new mining methods and techniques to reduce polluting discharges has been initiated and is being accelerated. Section 14 of the Federal Water Pollution Control Act emphasizes field-scale demonstration of methods and techniques for control and elimination of pollution caused by mine drainage. This program will place particular emphasis on the engineering and economic feasibility and practicability of pollution control methods.

Funds (in millions of dollars) expended by EPA for mining pollution during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
3.43	2.71	4.52

MUNICIPAL POLLUTION CONTROL TECHNOLOGY

Environmental Protection Agency

The objective of this program is the development, evaluation, and demonstration of improved and lower cost technology and methodology for treating and controlling pollution from municipal sewered wastes, storm sewer discharges, combined storm and sanitary sewer overflows, nonsewered urban runoff, and joint municipal industrial wastes. Included in this program will be development and demonstration of reliable and highly efficient waste treatment technology for removal of phosphorus from sewage methods, other than separation of sewers, for control and treatment of combined sewer systems. This program also includes control of combined sewer overflows by maximum use of flow control and retention.

Emphasis includes development and demonstration of technology and systems for the removal of bacteria and viruses, nutrients (especially nitrogen), and refractory organic wastes.

In-sewer treatment of municipal sewage and wastes from individual homes or small clusters of homes will continue. Emphasis will continue on the opera-

tion of municipal treatment systems at increased efficiency and reliability, determining the effects of industrial wastes on municipal waste treatment plants to provide criteria for assigning constraints on industrial waste loads. Determination will be made of the pollution characteristics and impact of urban storm water discharges and development of applicable means of control or treatment, or both, and development of means for controlling pollution from nonsewered urban runoff.

Funds (in millions of dollars) expended by EPA for municipal pollution during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
12.13	10.45	9.82

National Science Foundation

The application of hyperfiltration or reverse osmosis methods which were developed for desalination to a wide range of practical situations in which wastes must be removed from liquids is being studied. Results with wastes generated from fabric dyeing have been sufficiently promising for local development of a working configuration. Techniques for the removal of poisonous metals are being emphasized. Research programs will also investigate the environmental aspects of trace contaminants and the application of advance technology to urban engineering problems.

Funds (in millions of dollars) expended by NSF for municipal pollution during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.35	0.35	0.43

OTHER WATER QUALITY PROBLEMS

Atomic Energy Commission

Funds (in millions of dollars) reportedly expended by AEC for other water quality problems during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
6.80	8.10	9.29

Corps of Engineers

The primary use of pesticides has been to combat the growth and expansion of aquatic plants and their impact on navigable streams along the Gulf and Atlantic coasts. Realizing the detrimental effect of pesticides on ecology, the CE developed a research program to combat plant growth and minimize the environmental impact in achieving this goal. The program has two primary objectives: (1) To find herbicides that are the least harmful to the environment and (2) to develop other techniques that will accomplish the objective and not affect the environment. Part 2 of the objectives is discussed in the chapter entitled *Alternatives to the Use of Pesticides.*

Funds (in millions of dollars) expended by CE for other water quality problems during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.09	0.18	0.21

Department of Agriculture

Sediment is of concern in that it degrades water quality for recreation, irrigation, aquatic life, and industrial uses. It also serves as a carrier for other pollutants, such as phosphorus and pesticides. Sediment physically reduces channel capacity of rivers, estuaries, streams, canals, and ditches; reduces storage capacities of lakes and reservoirs; and often makes untreated water unsuitable for recharging groundwater supplies. Agriculture land is the source of one-half of all sediment. Sources of erosion, or sediment production on land, must be identified and control measures developed. Current studies are designed to provide better information on sediment trap efficiency as a guide in the development of improved reservoir design criteria. Significant attention has been given recently to the role of sediment in the chemical and biological quality of the impounded water to deteriorate.

Information is needed on sediment—water equilibria to accurately define that fraction of trace elements, phosphates, or other materials that are biologically active. Certain types of sediment may actually remove phosphate from solution. Chemical, physical, and biological properties of sediment must be characterized in terms of their effect on overall water quality.

Funds (in millions of dollars) expended by USDA for other water quality problems during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
2.12	2.11	2.18

Department of Commerce

Pollution abatement was initiated by the Maritime Administration as a result of coming into force of the

1954 International Convention for the Prevention of Pollution of the Seas by Oil by implementing national legislation (The Oil Pollution Act of 1961). The 1954 Oil PollutionConvention established a legal limit of 100 p.p.m. for oil or oily mixtures discharged from ships within certain prohibited zones, generally 50 miles from land. To meet the statutory and international requirements, a program was estabIsihed to develop equipment suitable for shipboard use to reduce the oil content of oily bilge and ballast water discharges to within the legal limits.

Attempts to develop both oil/water separation equipment and instruments for detecting and monitoring oil concentration have been taken. Methods of measuring the concentration of oily water discharges are still being sought, with several approaches now being considered.

A broad range of antipollution work has been undertaken toward the solution of problems in the following areas:

1. Elimination of international oily discharges from tankers.
2. Development of double-skin and high depth tanker designs.
3. Survey and evaluation of port reception facilities for shoreside treatment of oily wastes, oil water concentration, and interface detector systems.
4. Use of flocculents to aid in the separation of oil in oily ballast tanks.
5. Profile studies of oil concentration in ballast tanks.
6. Efforts to quantify ship pollutants other than oil.
7. Studies of different approaches to oil and ballast loading of tankers.
8. Collision avoidance.

Further plans will be directed toward solving other ship generation pollution problems, such as sewage, galley and garbage grinder liquid wastes, trash and solid wastes, and stack gases.

Funds (in millions of dollars) expended by DOC for other water quality problems during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.09	0.18	0.21

Department of Defense

The DOD is improving concepts, designs, and construction methods to minimize the effect of the construction facilities on the environment. These efforts contribute directly to the abatement of water pollution through control of soil erosion.

Research was undertaken to develop master planning, design techniques, and improved maintenance and disposal operations to reduce pollution from military construction activities. Construction engineering laboratories are collecting and analyzing information on requirements, criteria, and state-of-the-art in antipollution aspects of military construction.

Funds (in millions of dollars) expended by DOD for other water quality problems during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.07	0.07	0.13

Department of Transportation

This program is to develop techniques and equipment to control and clean up pollutant spills. Past and current activity has been directed towards developing these capabilities for oil spills. The oil spill program is approximately 40 percent complete. Development of oil spill control equipment is in the experimental prototype construction stage. Research into the fluid mechanics of oil films on the ocean surface and the hydrodynamics of floating barriers at sea was completed in support of the prototype development effort. Engineering research for oil recovery systems, including analysis of sorbent materials and engineering feasibility studies of various harvesting concepts, is nearing completion. Development of high seas qualified recovery systems has been initiated.

Longer term R. & D. activity will be concerned with providing similar control and cleanup capability to combat other hazardous pollutant spills.

Funds (in millions of dollars) expended by DOT for other water quality problems during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.41	3.61	2.50

Environmental Protection Agency

The objective of this program is the development and demonstration of technology and systems to control, effectively and economically, pollution from diverse sources, including recreational activities, watercraft, construction projects, impoundments, salt water intrusion, natural pollution, dredging and land fill, and spills and discharges of oil and hazardous materials.

Major emphasis has been given to means of preventing and controlling spills of oil and hazardous materials, including demonstration of technology for cleaning oil-contaminated beaches, development of procedures for evaluating oil-treating chemicals, development and evaluation of techniques for detecting oil discharges, and development of first-generation technology for oil containment and removal.

Objectives include: Development and demonstration of effective methods to prevent, detect, contain, and clean up oil pollution; development of technology and systems to preclude convenience dumping of used oils; exploration of techniques to prevent and mitigate the effects of spills of hazardous materials; and development and demonstration of technology to control and treat waste from watercraft, isolated recreation areas, construction sites, and dredging and landfill.

Funds (in millions of dollars) expended by EPA for other water quality problems during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
1.89	2.77	10.83

National Science Foundation

Research relates to enrichment pollution of lakes and rivers—the overgrowth of algae as a result of the addition of excessive nutrients to natural water. Other research relates to the biogeochemistry of heavy metals in both fresh water and the ocean. There is a definite and desirable trend toward the study of the biogeochemistry of heavy metals. Research is supported on sediment transport in streams and rivers and sediment deposit in quiet water. Additional research concerns the basic processes of sewage treatment—filtration and sludge formation.

Studies of algal and rooted-plant overgrowth are supported on understanding the natural processes, such as the feeding of herbivores, that will help control aquatic plant populations.

Funds (in millions of dollars) expended by NSF for other water quality problems during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.86	0.75	0.82

SALINITY RESEARCH

Department of Agriculture

USDA is primarily concerned with the occurrence of dissolved salts, metals, metal compounds, acids, and alkalis in irrigation water, their accumulation in soils, and subsequent augmentation in drain outflows from irrigated cropland in arid regions.

Current research is directed toward increasing irrigation efficiency to achieve better control of salinity in irrigated areas. Attention is also being given to means of minimizing evapotranspiration losses. Methods are being studied whereby natural water yields from surrounding areas can be increased to dilute salt concentrations.

Additional research is designed to gain an understanding of the physiology of salt tolerance in plants, and to genetically increase the salt tolerance of existing crops, thus permitting greater use of more saline waters for existing crops.

New methods should be explored for disposing of saline drainage water to avoid degrading existing water resources. Possible alternatives include desalination, evaporation basins, deep well injection, and diversion to the sea or other saline water bodies such as the Salton Sea.

Where adequate good quality water is unavailable for irrigation, methods should be developed for using water of impaired quality. This would include the potential reuse of return flows. Greater efforts are needed in the genetic development of more salt tolerant crops.

Funds (in millions of dollars) expended by USDA for salinity research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
1.35	1.42	1.51

Department of the Interior

Model studies and conceptual design of outfalls and intakes are designed to minimize the effects of thermal and increased salinity discharge from distillation desalting plants. Intake studies are being investigated to determine the most effective and economical intake structures and antifouling devices in order to minimize the amount of marine life present in feedwater.

Ecological systems of coastal and inland waters are studied to establish changes that may be brought about by introducing large volumes of waste brine from desalting plants. The synergistic effects of increased salinity and copper concentrations, together with elevated temperature, will be studied.

The Office of Saline Waters is attempting to develop processes for converting geothermal brines to desalted water without deleterious side effects on the

environment. Process studies and tests will be conducted to determine methods of minimizing thermal pollution of the atmosphere, of recovering useful by-products that might otherwise lead to disposal problems, and of disposing of wastes in an innocuous manner.

At inland locations that have high solar evaporation rates, solar ponds can be used as a method of brine disposal. Related R. & D. studies and tests include preparation of specifications for construction of solar evaporation ponds.

A method of brine disposal in inland areas is ultimate disposal in deep wells. The technical considerations include the study of geological formations to determine their feasibility for receiving large volumes of waste brine and the possible hazards of dumping brine into subsurface formations over long periods.

Dissolved salts in irrigation water, their accumulation in soils, and subsequent augmentation in drain outflows from irrigated cropland in arid regions are of concern. There are about 30 million acres of irrigated land in the 17 Western States. Salinity is a potential problem on about one-half of this acreage, and over 8 million acres have been adversely affected by salt accumulation.

Current programs are directed toward increasing irrigation efficiency to achieve better control of salinity in irrigated areas and to means of minimizing evapotranspiration losses. Methods are being studied whereby water yields from surrounding areas can be increased to dilute salt concentrations. Phreatophytes are responsible for significant transpiration losses and control measures are being studied.

Consideration also must be given to the effects of saline water on crop production. Current programs are designed to evaluate the physiology of salt tolerance in plants.

Irrigated arid agricultural lands will continue to be needed in the future to meet demands for food and fiber crops. Where good quality water is not available, soil-water-plant management systems must be developed that will permit use of inferior quality water. Greater efforts are needed to develop soil-water-plant systems that reduce losses by evaporation and transpiration and that better control water losses through phreatophytes and seepage.

Where good quality water is unavailable for irrigation, methods are needed for using water of impaired quality. This would include the potential reuse of return flows. Greater efforts are needed in the genetic development of salt tolerance of living organisms. Where a possibility of agricultural water quality impairment from industrial sources exists, more information will be needed on the impact of certain trace metals on both plants and animals.

Funds (in millions of dollars) expended by DOI for salinity research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
1.60	1.70	1.87

THERMAL RESEARCH

Atomic Energy Commission

The R. & D. supported on thermal additions include the following:

- Development of improved water temperature predictive techniques in streams, lakes, estuaries, and oceans.
- Development of improved heat dissipation systems for thermal power plants.
- Determination of the effects of siting large nuclear powerplants on large bodies of water, and performance of economic and social factors.
- Determination of the biological effects of temperature and temperature changes on various water systems; that is, in fresh-water streams and lakes, in bay or other coastal environments, and in the atmosphere. Emphasis is placed on the effects of sublethal temperatures and other environmental stresses as they relate to the optimal growth of sport and commercial fish and supporting ecosystems.
- Development of beneficial uses for thermally enriched water for application in such fields as agriculture, aquaculture, and some industrial agencies.

Funds (in millions of dollars) expended by AEC for thermal research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.85	1.49	3.25

Corps of Engineers

The Civil Works study of thermal effects on rivers and lakes has included monitoring temperature regimes, thermal destratification, and water quality. Monitoring of temperature regimes is conducted pre- and post-impoundment in order to determine the project's effect on ecological balance and the impact of the regional environment. The thermal destratification investigations have evaluated the use of air

diffuser systems or submerged wires on temperatures in stratified lakes, effects of temperature change on water quality and sedimentation, and structural changes that would allow downstream releases or releasing water from various levels of lakes and reservoirs in order to offset thermal impacts.

Funds (in millions of dollars) expended by CE for thermal research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.19	0.20	0.21

Department of Commerce[10]

NOAA of DOC is reported spending the following amounts (in millions of dollars) on thermal research during fiscal year 1969–71:

1969	*1970*	*1971*
0.27	0.20	0.15

Department of the Interior

The DOI's Office of Water Resource Research is concerned with the following pollution programs: Ecological impact of waste heat, heat dissipation, temperature distribution, and constructive use of waste heat.

Additional research emphasis is needed in the following areas: The effects of temperature on the survival growth, reproduction, and well-being of important animals and plants in the aquatic ecosystem, and on food chain organisms; interaction effects on ecosystem of temperature, dissolved oxygen, salinity, nutrients, and other factors; development of non-empirical stochastic temperature prediction models; development of three-dimensional mathematical models for predicting temperature distribution; improving heat dissipation methods as alternatives to once-through cooling; and constructive use of waste heat; for example, in agriculture, in aquaculture, to enhance recreational quality of water, and for industry and dwellings.

Research by the U.S. Geological Survey is concerned with describing the physical processes affecting water temperature and with defining some of the biological effects of thermal pollution. Research projects deal with heating and cooling at the air-water interface, evaporation effects, mixing, diffusion, effects of urbanization on stream temperatures, circulation in stratified lakes and estuaries, instrumentation and techniques for measuring water temperatures by continual monitoring and by remote sensing, and biological effects resulting from heated discharges in an estuary.

Funds (in millions of dollars) expended by DOI for thermal research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.35	0.49	0.52

Environmental Protection Agency[11]

The objectives of the thermal pollution research program are:

1. To improve the basis for developing and implementing thermal standards by determining the effect of temperature cycles on the reproduction and life cycle of marine estuarine and fresh water aquatic life, fish and essential feed chain organisms.
2. To improve techniques for the control of waste heat through development of advanced cooling techniques, power generation systems that minimize waste heat, beneficial use of waste heat and techniques for predicting temperature patterns in receiving waters.

Funds (in millions of dollars) expended by EPA for thermal research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.85	1.75	2.87

Housing and Urban Development

Most facilities for generating electricity burn fossil or nuclear fuel and in addition to electricity, they produce tremendous amounts of low-temperature thermal energy, which, at present, is discharged into water and atmospheric sinks. The discharge into water has created concern for thermal stream pollution that is bound to increase with power system growth.

[10] Expenditures on thermal research for the National Oceanic and Atmospheric Administration, DOC; EPA; and TVA were obtained from the OST report "The Effects and Control of Heated Water Discharges" (November 1970). No direct input on funds spent or program descriptions were obtained from the agencies themselves.

[11] Expenditures on thermal research for the National Oceanic and Atmospheric Administration, DOC; EPA; and TVA were obtained from the OST report "The Effects and Control of Heated Water Discharges" (November 1970). No direct input on funds spent or program descriptions were obtained from the agencies themselves.

Demonstration of effective and economical control of thermal pollution and beneficial use is now wasted heat. The present effort is concentrated on the analysis of an energy center for a new city.

Funds (in millions of dollars) expended by HUD for thermal research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.10	0.10	0.10

National Science Foundation

Research support in thermal pollution is oriented to a broad program in all sciences and engineering. Support by the Divisions of Engineering, Biological and Medical Sciences, and Environmental Sciences is specifically oriented to thermal pollution in water. NSF supports 90 grants in the area of heat transfer. Water and related problems in heat transfer research include: The impact of urbanization; the mixing and transfer processes for heated effluent in open channels, rivers, lakes and oceans; the utilization of city utilities for the discharge of power plant heat; and ecological and physiological effects of thermal discharges on animals and fish.

Funds (in millions of dollars) expended by NSF for thermal research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.74	0.89	0.90

Tennessee Valley Authority[12]

The Tennessee Valley Administration is reported as spending the following amounts (in millions of dollars) on thermal research relating to water:

1969	*1970*	*1971*
0.24	0.42	0.42

WASTE TREATMENT AND ULTIMATE DISPOSAL

Atomic Energy Commission

Funds (in millions of dollars) reportedly expended by AEC for waste treatment and ultimate disposal during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
3.31	3.10	3.44

Department of Defense

The Army is attempting to reduce water-polluting effluents from Army laboratories, testing facilities, munitions plants, and facilities of the Field Army. The following studies are being conducted to find better methods for decontamination of toxic wastes from Army facilities and test sites: To develop kits for detecting the effectiveness of the decontamination of water; to improve techniques for disposal of sewage in cold regions; to recycle waste water in field hospital systems; and to apply tertiary treatment to sewage by exposing it to gamma radiation. It has been shown that irradiation of sewage destroys almost 100 percent of the microorganisms present before tertiary treatment. A water recycling and waste management system is now undergoing engineering and serviceability tests. Progress has been made in treatment of sewage in cold regions without having to place the facilities inside heated buildings.

For treating photographic film wash water for reclamation, the Air Force is evaluating an electrolytic technique to regenerate and reuse the photographic bleach without introducing chemicals into the process effluent. Treatment techniques for electroplating waste will be studied. Work also will be accomplished to develop air transportable sewage treatment systems and the design criteria for sewage oxidation/stabilization ponds. Equipment designed to process waste water up to near potable standards for reuse in showers, laundries, and others is to be developed for contingency deployments. This new effort is for the primary purpose of reducing raw water requirements but in areas where no shortage exists, pollution reduction could be a beneficial byproduct.

Funds (in millions of dollars) expended by DOD for waste treatment and ultimate disposal during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.59	0.96	1.00

Department of the Interior

The environmental research program provides fundamental research for new approaches that can be further explored in the engineering development program. The research program is broad-gaged in

[12] Expenditures on thermal research for the National Oceanic and Atmospheric Administration, DOC; EPA; and TVA were obtained from the OST report "The Effects and Control of Heated Water Discharges" (November 1970). No direct input on funds spent or program descriptions were obtained from the agencies themselves.

scope and is broken down into major categories as follows: Selective removal or addition of ions to water, scale prevention and control, iron and manganese removal, and pH control.

A multistage flash pilot plant was operated on the polluted waters of the Hackensack River in New Jersey to determine the technical feasibility of the distillation method of purification.

Funds (in millions of dollars) expended by DOI for waste treatment and ultimate disposal during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.09	0.11	0.13

Department of Transportation

Current work is centered on applied research for improving sewage treatment processes and developing sewage plants suitable for shipboard use to prevent water pollution by ship discharges.

Current and short-term activity is being directed towards applied research insolids separation technique, improved disinfection methods, procedures to accomplish tertiary treatment, and development and field test of experimental treatment systems.

Funds (in millions of dollars) expended by DOT for waste treatment and ultimate disposal during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.10	0.11	0.30

Environmental Protection Agency

The objective of this program is to develop waste treatment technology applicable to both municipal and industrial wastes. Immediate emphasis will be given to cooperation with municipal pollution control technology program in concentrating efforts to convert emerging technology into rapid development to maximally impact attainment of water quality standards through federally aided construction of municipal waste treatment plants.

Short-term goals include: Development of methods for effective and economical removal of nitrogen, development of methods for handling sludges and brines from municipal and industrial waste treatment, development and demonstration of technology for waste water renovation and reuse, and development of systems, including automated systems, for reduction of cost and increase of reliability and efficiency in the operation of municipal waste treatment plants.

The long-term goal is development of technology for the efficient and reliable treatment of all point source waste discharges to whatever level of quality, including potable water, required to meet water quality standards.

Funds (in millions of dollars) expended by EPA for waste treatment and ultimate disposal during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
11.67	7.26	5.35

National Aeronautics and Space Administration

Part of the challenge of long duration, manned space missions lies in the development of life support systems and equipment that can minimize large quantities of expendables; safely collect, process, and dispose of human waste, expendables, and food residue for possible reuse; and monitor and control contaminants. Some of the R. & D. to meet these requirements may be applicable to water pollution abatement. The technology developed may be demonstrated to be of importance to pollution control.

Funds (in millions of dollars) expended by NASA for programs applicable to waste treatment and ultimate disposal during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.70	0.98	1.28

GENERAL WATER QUALITY RESEARCH

Corps of Engineers

Under part of the civil works research program, data are collected in order to accomplish investigation of the effects of CE's water resources projects on the ecological regime. This data collection effort includes information on physical, chemical, and biological parameters gathered at specified river stations, reservoirs, and coastal inlets and estuaries.

In addition to the data collection effort, CE is attempting to develop technology to assist in achieving high standards of water quality. A major investigation is aimed at utilizing mechanical aeration on deep multipurpose impoundments to prevent or lessen seasonal stratification and improving temperature effects and the dissolved oxygen content of stored and released waters. Further research is planned on determining the energy requirements

necessary to completely mix the body of water and maintain stability during the summer. A second research effort to improve the oxygen and nitrogen content in water to preserve fish has led to the development of mathematical and hydraulic models for the prediction of oxygen and nitrogen levels and evaluating design criteria and operation of spillways and outlets to minimize detrimental nitrogen concentrations.

Funds (in millions of dollars) expended by CE for general water quality research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.10	0.14	0.87

Department of Commerce

The DOC's National Bureau of Standards is studying detection and measurement of trace organic pollutants in water, based on the use of aqueous solutions on an inert substrate in gas chromatography. In principle, the method will be applicable to analysis for a wide range of organic compounds or classes and, where developed, will eliminate much sample handling, concentration, extraction, etc. Future priority research areas will be fluid velocity and volume flow measurement, development of standard reference materials most needed for calibration of analytical instruments, and development of electrochemical techniques for trace analysis and for analysis of concentrated solutions such as raw industrial wastes.

The Nashus River demonstration program for environmental management attempts to demonstrate that by focusing and directing a concentrated, intergovernmental effort in one river basin and by using maximum available water quality management tools, water quality standards and reclamation of desired uses can be achieved in a near-optimum and efficient manner.

Funds (in millions of dollars) expended by DOC for general water quality research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.25	0.25	0.58

Department of the Interior

Identification of pollutants is being studied to develop faster, more reliable, and more sensitive methods, especially for elements and compounds not previously of concern, such as heavy metals and persistent pesticides.

Investigations are concerned with diffuse sources of pollutants and transport and fate. A significant amount of research effort is devoted to the complex pathways and ultimate fate of phosphorous and to the biological concentration of persistent pesticides in the food chain.

Studies on the effects of pollutants involve research on how a wide variety of pollutants affect beneficial uses of water. Pollutants include excess organic matter, pesticides, nutrients, and industrial wastes.

Research in waste treatment is directed at physical, chemical, and biological methods of improving the quality of effluents and reducing costs. Special attention is given to reducing nitrogen, phosphorous, and pesticides; to reducing industrial, textile manufacturing, and acid-mine wastes; and to adapting sewage treatment methods to animal feedlot wastes.

Water treatment research is aimed at treatment methods to make water supplies safe, suitable, and economic. Current research includes innovative methods to remove undesirable elements (foam fractionation, synthetic flocculants, electrophoretic clarification); evaluation of disinfectants for viruses, desalination techniques, and virus removal by chemical flocculation.

Water quality control studies include instream aeration devices, decontamination of radioactive substances in mine wastes, destratification of reservoirs to improve water quality, recycling water, reclaiming wastes, and productive use of wastes to grow forest and field crops and aquatic animals of economic value.

Other program areas related to the quality of water environment are as follows: Improving water resources system planning and management processes, conserving ecologic values in water resources planning, and conserving estuarine water resources.

The U.S. Geological Survey (USGS) operates a program to appraise the Nation's water resources and to assure that water information needed to manage these resources effectively is available. The agency also is charged with the responsibility to coordinate a national network for acquiring water data. Research by the Survey covers many parts of the water cycle, including water quality. In addition to research monies shown in this report, $5.20 million is being spent on monitoring and surveillance of water quality, and about $26 million is being spent on water resources investigations and data coordination applicable to the control of water quality.

Considerable progress has been made by the USGS on developing analytical techniques, and research will continue to stress identification of substances.

Considerably more effort is to be placed on analyzing organic compounds, materials sorbed by sediments, and toxic heavy metals. Neutron activation analysis has increased detection sensitivity. More reliable continuous monitors are being developed. There is encouraging evidence that some remote-sensing methods may be applied to water analysis, and these techniques are being studied further. Research continues on improving techniques for measuring and computing sediment transport.

Research is continuing to help understand the basic processes, such as chemical reactions, mixing, sedimentation, erosion, aeration, and sorption, that control water quality. This is coupled with research to develop a better understanding of larger hydrologic systems.

Research on pollution by the Geological Survey includes several projects on the pollution of groundwater from deicing salts, landfills, septic tanks, injection wells, and other sources. A major research effort recently started by the USGS is concerned with subsurface waste storage.

High priority will be placed on research, development, and demonstration projects on many aspects of surface and subsurface waste disposal. Research in such areas as instrumentation, evaporation, limnology, and estuarine circulation also has application in understanding and solving thermal pollution problems. This work has made significant progress toward such objectives as developing instruments to record and telemeter thermal data and other information accurately, understanding the basic processes of heat and vapor transfer at the air-water interface, understanding circulation and tidal flushing of bays and estuaries.

The Bureau of Reclamation is finding new and better ways to protect the quality of water resources so that available supplies are not rendered unfit for use and so that environmental and ecological balances are not violently upset.

Water quality control studies involve control of surface and ground water quality by such methods as reaeration of reservoir and river waters; better management of ground waters, impoundments, and streams; and determination of potential effects of residues of selected herbicides used for infestation control. Reaeration studies will establish practical methods of treating large-scale reservoir releases to safely increase the dissolved oxygen content of the waters. Herbicide residue studies are made to determine the fates of such residues in relation to methods of herbicide application. Research in predicting nutrient and salt loadings enables the development of evaluation procedures for determining, before projects are built, the amounts of such materials that will be in the return flows from the project and gives insight into the treatments that will be required.

Funds (in millions of dollars) expended by DOI for general water quality research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
9.46	9.25	10.59

Department of Transportation

The Coast Guard is developing adequate methods for detecting the presence and sources of pollutants spilled in the coastal ocean environment and navigable inland waters. This will provide information concerning pollutant behavior so that proper corrective action can be taken and will improve enforcement capabilities.

Past and current activity is centered on the development of airborne, all-weather sensors to detect, map, and quantify oil spills. Studies on ultraviolet, infrared, visible, and microwave portions of the electromagnetic spectrum have been completed. Development of experimental sensor systems based on this research is underway. Short-term R. & D. is directed towards developing a positive method to identify the source of an oil spill. In addition, research to determine the routes and reservoirs of spilled oil is in progress. Long-term work in this program will extend remote sensing, source identification, and forecasting capability to include marine transportation-related hazardous polluting substances.

Funds (in millions of dollars) expended by DOT for general water quality research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.20	0.55	1.20

Environmental Protection Agency

This program includes characterization and quantification of sources and kinds of pollutants and their interaction with the water environment, development and demonstration of technology or systems for preventing and controlling pollution from multiple sources such as accelerated eutrophication and thermal pollution, development and demonstration of means for the control of pollution other than by

waste treatment, and an increased understanding of the socioeconomic, legal, and institutional aspects of pollution.

Significant progress has been made in characterizing the causes of accelerated eutrophication and in the development of analytical methodology. Major goals include: Development of methods to control eutrophication and restore degraded lakes; and development and standardization of methods to detect, identify, quantify, and trace water contaminants to detect impending problems, to assume compliance with regulatory action, and to relate pollution discharge loads to receiving water quality. Specific programs recently authorized include: Lake restoration in which development is underway for methods of controlling eutrophication by advanced waste treatment, nutrient removal, weed harvesting, and chemical inhibition of algae. (This program will provide for full-scale demonstration of these and other techniques.) Great Lakes pollution control in which initial projects will be aimed at identifying and characterizing problem areas to be the subject of full-scale control demonstrations; and Alaska village demonstrations in which demonstration, including through adaptation of temperate climate technology, of systems for provision of safe water, and controlling or eliminating water pollution in native villages of Alaska.

Funds (in millions of dollars) expended by EPA for general water quality research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
10.69	13.47	22.78

Tennessee Valley Authority

TVA carries on water quality research and development related to methods of controlling various types of pollution or pollutional effects associated with river basin management. The following activities are under way:

1. Studies to determine the causes and effects of reservoir eutrophication.
2. Studies of rate of heat loss from water.
3. Studies of the effects of heated water on aquatic life.

Funding (in millions of dollars) expended by TVA for general water quality research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.44	0.48	0.53

WATER QUALITY REQUIREMENT RESEARCH

Environmental Protection Agency

The objectives of this program are to provide the scientific bases for establishing improved water quality standards for the Nation's waters and to develop a capability for predicting the water quality effects of the many new substances being constantly introduced into the water environment.

Investigations have been focused on all water uses but primarily on effects of pollutants on aquatic life, on the assumption that standards adequate to protect this life will most likely also provide water quality sufficient for other water uses. Research involves establishment of refined water quality criteria for heavy metals, pesticides, petrochemicals, temperature and dissolved oxygen, complex industrial effluents, and such specific chemicals as polychlorinated biphenyls (PCBs) and Nitrilotriacetric acid (NTA).

Funds (in millions of dollars) expended by EPA for water quality requirements research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
4.05	5.49	10.38

Land Quality

Pollutants cannot be restricted to a single medium such as land, water, or air. Pollutants in or on land may be transported to water, or they may be carried by wind currents or volatilized into the air. The extent to which this occurs cannot be determined precisely. Thus, arbitrary decisions had to be made on how to classify the effects of specific pollutants. For example, animal wastes are considered in part in the discussion of solid wastes and also under the specific heading of animal wastes. Despite the seeming duplication, discrete elements of the total effect have been separated. There is no duplication in funds reported in table 5 (p. 34).

R. & D. relative to pesticides has also been a problem in classification. Considerable research is being conducted on the effects of pesticides on fish and wildlife, on domestic animals, and on the food quality. For want of a better place to include such research within the organizational format of this report, it is reported in this appendix. The reader should be aware, however, that such research does not relate specifically or exclusively to land quality.

This appendix is organized by pollutants of various kinds that affect land quality. Under each pollutant, the activities of the various Federal agencies who have R. & D. programs in that area are discussed.

ANIMAL WASTES

Department of Agriculture

Estimates indicate that animal wastes as voided total about 1.7 billion tons annually. Suitable methods for handling and disposing of these wastes to avoid soil, water, and air pollution are needed to enhance environmental quality. There is a growing public concern about insects breeding in waste materials and the danger of disease transmission.

To maintain economically competitive positions, producers have had to specialize, automate, and increase the size of their operations. Specialization has often eliminated cropland that would otherwise be available for land disposal of animal wastes. Automation has resulted in greater concentrations of livestock. Currently, more than one-half of the wastes arise from these highly specialized, concentrated operations. The percentage is increasing.

The general practice in poultry and beef cattle operations is to allow the wastes to ac mulate for several months, with ultimate disposal o. croplands. These disposal methods require better understanding of the reaction of manure in soil. Preliminary data suggest that sugarbeet and corn yields were not reduced by cattle manure treatments of 200 tons per acre per year. Above this rate, plant injury from salts occurred early in the season. In Arkansas, over 200 head of cattle were lost from disorders associated with high nitrates when farmers put heavy applications of poultry litter on forage crops.

Limited data on nitrate pollution of surface and ground waters from a feedlot on a level site underlain by sandy soils and a shallow water table indicate that denitrification occurs. However, the amount of nitrogen lost to the air is not known. The data suggest that feedlots can be constructed so that manure will decompose without polluting the surface and ground waters.

Funds (in millions of dollars) expended by USDA for animal wastes research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.49	0.60	0.92

FOREST AND CROP RESIDUES

Department of Agriculture

Recent restrictions on burning of crop wastes, brought about by air pollution laws, have raised

questions about the biophysical and biochemical relationships that occur during residue decomposition. Agricultural scientists are aware that the knowledge of management practices as they relate to residue decomposition is very limited.

For example, because of lack of knowledge about residue decomposition, no alterative methods have been found for the annual burning of residues from some crops.

Funds (in millions of dollars) expended by USDA for forest and crop residues research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
2.36	2.51	2.88

HEAVY METALS

Department of Agriculture

A partial understanding has been attained of the reactions of metals such as arsenic, copper, zinc, mercury, and cadmium with soils. Some of these metals will become soil pollutants from agricultural operations, others from industrial sources.

Funds (in millions of dollars) expended by USDA for heavy metal research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.06	0.06	0.06

National Science Foundation

NSF has recently undertaken research on the effect of biological processes on mercury and lead. The mercury study focuses on methylation of heavy metals by the anaerobic bacteria and is designed to develop a general model of heavy-metal methylation that may apply to a variety of heavy metals. This in turn may be of ultimate use in anaerobic waste treatment. The lead study seeks to determine the significance of lead ingestion by migratory waterfowl, particularly from bottom-rooted plants that may have absorbed the heavy metal. The study may bear on the cycling of an important industrial pollutant.

Funds (in millions of dollars) expended by NSF for heavy metal research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.10	0.10	0.50

INDUSTRIAL PROCESSING WASTES

Corps of Engineers

Research is underway to determine the ecologic impact of depositing unpolluted dredge spoil on salt marshes and to use spoil for developing man-made marshes. Effect of these activities on water quality is also being studied.

Funds (in millions of dollars) expended by CE for industrial processing waste research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
---	---	0.03

Department of Agriculture

Liquid wastes from food and other industrial processing plants can be a serious pollution problem. If liquid wastes contain high levels of organic materials, the biochemical oxygen demand can reduce the oxygen level in reservoirs or streams to a level that is lethal to aquatic life. Effluents that are high in heavy metals can be poisonous to aquatic life under anaerobic conditions.

Soil is an excellent disposal medium. Most organic solids in processing wastes decompose readily in soils; however, inorganic compounds may accumulate to levels hazardous for some plants. High plant uptake of these compounds may be a hazard to man and animals.

Wastes from industrial areas vary widely in their chemical composition. For example, effluents from areas with food-processing plants have low levels of the heavy metals but high levels of dissolved organic materials. If the dry-caustic process for peeling potatoes is used, the liquid wastes can contain high levels of sodium. Disposal of these materials in soils on a sustained basis can create serious physical problems in the soil.

Funds (in millions of dollars) expended by USDA for industrial processing waste research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.19	0.21	0.22

Tennessee Valley Authority

Restoration of surface-mined land is important in assuring an attractive environment and protecting land and water resources. Through research, demonstrations, and technical assistance, TVA works for the restoration of all abandoned surface mines in the

Tennessee River basin and for the assurance that reclamation is an integral part of future mining operations.

Studies are conducted in cooperation with the U.S. Forest Service, the States, and with the mining industry and landowners to discover better methods of reclamation. Demonstrations established with cooperators show how substantial areas of strip-mined land can be restored to timber and wildlife production, that water can be controlled, that stream pollution from acid and silt can be reduced, and that results need not be costly and will begin to show in a relatively short time. TVA has proposed that a cooperative Federal-State-landowner demonstration of the development of orphan strip-mine lands be undertaken.

Funds (in millions of dollars) expended by TVA for industrial processing waste research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.20	0.30	0.10

PESTICIDES RESEARCH

R. & D. programs related to the effects of pesticides on land quality are conducted by USDA, AEC, DOI, and HEW. Programs conducted by them include both basic and applied efforts.

Atomic Energy Commission

The AEC program on pesticides is conducted extramurally. Two projects involve the study of DDT recycling in terrestrial ecosystems.

Funds (in millions of dollars) expended by AEC for pesticides research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.05	0.03	0.03

Department of Agriculture

R. & D. relating to land pollution by pesticides is conducted by USDA primarily to determine the behavior and fate of pesticides in soil and to avoid or minimize solid contamination by pesticides and their metabolites. An added activity is the disposal of pesticides and their containers.

Mixing with soil increases the decomposition rates of certain pesticides. Some pesticides are rapidly degraded by soil microorganisms, others only incidentally during the process of microbial decomposition of organic matter. Chemical degradation occurs rapidly or slowly, depending on chemical characteristics of the soil and the specific pesticide type involved. Most pesticides appear to be noninjurious to soil microorganisms. Pesticide use schedules have been modified by substitution of less persistent pesticides, or by changes in dosage and timing, thereby reducing the pollution potential. Basic information on combustion products has permitted design of prototype incinerators for the safe and effective disposal of waste and excess pesticides.

A better understanding of the ultimate fate of pesticides and their metabolites in soils is needed. Studies have been and are being conducted on the mobility of pesticides in soil types ranging from sand to clay. Such studies are important in determining the potential for ultimate pollution of surface or ground water by pesticides. Studies are also underway on the microbial, chemical, and photochemical degradation of pesticides. Degradation pathways and rates of degradation have been determined for many pesticides. Research of this type is never ending. As new pesticides are developed, new research is essential to determine their fate in the soil and their effect on the biota.

Virtually all pesticides in the soil are absorbed by plant roots to a greater or lesser degree. Thus, their metabolism in plants becomes a primary concern. In addition, some pesticides, or their degradation products, may move into the soil from living plants or from the incorporation of dead plant material. Studies are underway to determine the metabolism of pesticides in plants and the identification of degradation products.

Toxicologic data on livestock have been developed for many pesticides. This information, together with studies of their fate and metabolism in plants and in soils, is useful in making adjustments to reduce or eliminate effects of pesticides. Limited data on effects of pest-control practices on wildlife have been developed.

Information on domestic animals is partly transferable to wild animals. Field tests of results from laboratories and small-scale plots are needed to permit accurate recommendations for safe and effective control of economic pests under field conditions.

Funds (in millions of dollars) expended by USDA for pesticides research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
8.68	8.69	9.81

Department of the Interior

R. & D. programs conducted by DOI in the field of pesticides are oriented toward determining their effects on fish and wildlife. The pollutants may originate in land or in water and air. Particular attention is given to the persistent organochlorine pesticides and their interaction with other chemicals in the environment. Many pesticides used in fish and wildlife management, such as piscicides, aquatic herbicides, insecticides to control disease vectors, lampricides, molluscicides, and various other animal control agents, need to be more thoroughly investigated. These materials do not have a large volume of use. Thus, the chemical industry does not have an incentive for their development. A good example is the effort that will be required to generate data for registration and establishment of a residue tolerance for a lampricide needed to save the recreational and commercial fisheries of the Great Lakes.

Funds (in millions of dollars) expended by DOI for pesticides research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
2.40	2.40	2.60

Department of Health, Education, and Welfare

The medium polluted may be water, air, or land, or a combination. Pesticide research projects are designed to obtain data for developing criteria to establish sound, acceptable standards of food safety and environmental quality. Pesticide research is supported to acquire information on the potential human health hazards of these chemical agents and to evaluate pesticide control methods to obtain optimum effects on target organisms with minimal hazards to nontarget organisms.

The National Institute of Environmental Health Sciences assesses the acute and chronic toxic effects of pesticides in the general population, studies metabolism of pesticides and their conversion products using animal experimentation, and conducts studies on prediction of toxicity in man. The pesticides research program includes studies on the basic mechanism of action, detoxification, fate of pesticides, effects on reproduction, and analytical methodology.

The National Cancer Institute has a sizable program of chronic toxicity testing on pesticides which is conducted by the carcinogenesis area. This activity is designed to identify those materials which produce carcinogenic effects in animals after prolonged exposure. In addition, extensive activities are carried out in both the intramural and collaborative research areas on the molecular events leading to the carcinogenic state which bear on the problems of pesticide toxicity.

The Food and Drug Administration (FDA) research on pesticides is designed to support and strengthen the establishment and enforcement of pesticide tolerances. Chemical research on pesticide residues in food includes chemical identity of the residue; developing, improving, and validating analytic methodology; and occasional checking of the validity of data submitted in petitions.

FDA's biological research includes the physiological effects and metabolism of pesticides in biological systems and an evaluation of their effects in terms of toxic action; toxicity studies to determine safe tolerance levels; and development of data on the direct effect of pesticides on man.

Funds (in millions of dollars) expended by HEW for pesticides research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
6.10	5.30	5.60

PLANT NUTRIENTS

Department of Agriculture

Agriculture's primary commitment is to the production of adequate food and fiber for our needs. Production efficiency is enhanced by practices that increase the net return to the farmer per unit of input. The use of commercial fertilizer is an effective method of increasing net return to the farmer. Most operators receive a good return for each dollar spent on plant nutrients.

Even though the use of nitrogen and phosphate has increased tenfold in the United States during the past 25 years, rates now used on most crops are below those needed for maximum yields. The knowledge of soil fertility, accumulated over many years, gives little insight into surface- and ground-water pollution from fertilizer use.

Attempts to assess the effluents originating on fertilized watersheds have been frustrating because of the difficulty of separating the fertilizer component from the contamination from livestock, organic matter, mineralization, and urban septic tanks.

Funds (in millions of dollars) expended by USDA for plant nutrient research during fiscal year 1969–71

are as follows:

1969	1970	1971
2.33	2.38	2.60

SALINITY

Department of Agriculture

Waters used for irrigation contain from a few hundred pounds to several tons of salt per acre-foot. Salt damage to soils and crops is a major problem of irrigated agriculture. Soluble salts are increasing in water used downstream as the irrigation of the Midwest and West develops. On the Atlantic coast, supplemental irrigation is becoming a necessity for growers for vegetables and other high cash-value crops. Soil salinity of natural origin is also a problem in a large acreage of the Great Plains.

In 1960, a survey showed that 30 percent of the irrigated land contained enough salt to require leaching for sustained production. Leaching can be accomplished, but there is evidence that more water is being used for this process than would be required.

Cropping, tillage, and mulching practices have been developed for minimizing the salinity problems in the Dakotas. Very little is known, however, concerning the management of shale soils in Montana and Wyoming.

Funds (in millions of dollars) expended by USDA for salinity research during fiscal year 1969–71 are as follows:

1969	1970	1971
0.76	0.80	0.85

SEDIMENT

Corps of Engineers

Sediment studies include the collection of suspended and bed load data, degradation data, aggradation and delta formation, investigations of sediment transport, and basic laboratory studies. One major effort is an interagency project for measuring and analyzing sediment load in streams and for developing new sediment sampling equipment.

Funds (in millions of dollars) expended by CE for sediment research during fiscal year 1969–71 are as follows:

1969	1970	1971
0.10	0.12	0.13

Department of Agriculture

In tonnage, sediment is still the principal pollutant in the world today. This problem arising from sheet and gully erosion, is responsible for the establishment of the Soil Conservation Service.

On the order of 4 billion tons of sediment are carried away by runoff and streamflow each year in the United States. Sediment is usually a liability. Specific efforts to reduce or manage its adverse effects are usually required for water and related land resource development.

Sediment yield from a watershed is a function of the amount of erosion in a watershed and the efficiency of the stream in transporting eroded material away from the watershed. Composition of sediments varies widely. Methods for relating sediment quantities and characteristics to source areas are lacking. The relationship between physicochemical properties of sediment and their influence on water quality and aquatic environments is unknown.

Methods for determining sediment yield by obtaining the difference between erosion and deposition are not satisfactory. Sediment delivery ratio values developed from reservoir surveys are expensive and provide only crude estimates. The rate and quantity of movement in channel beds are generally developed from mathematical equations, which frequently give widely differing results from the same set of conditions. Alternative methods for determining and predicting sediment yields are being conducted. The development and utilization of mathematical and physical models to determine sediment source, dispersion, and yield appear to offer promise.

Funds (in millions of dollars) expended by USDA for sediment research during fiscal year 1969–71 are as follows:

1969	1970	1971
3.03	3.15	3.37

SOLID WASTES

The solid wastes included in this section include primarily mining wastes, junk and urban refuse, and munitions. Some agricultural wastes are also included.

Department of Agriculture

USDA is working jointly with DOI and EPA on methods of recycling wood fibers present in municipal rubbish.

Ways are being sought to utilize wood wastes developed during logging and manufacture of wood products. Chemicals, paper pulp, particle board, and cattle feed are potential solutions. Logging wastes can be minimized in southern pines by genetic selection to produce trees with straight stems and resistance to fusiform rust canker disease.

The development of methods and facilities for handling, reclaiming, and disposing of farm animal wastes without environmental pollution is of paramount concern. An oxidation ditch has been operated one full cycle—from startup to cleaning. Runoff from open feedlots of varying slopes has been measured and the pollution potential evaluated. Some information has been collected on the contribution of animal wastes to air pollution. Analysis of soils below a level feedlot indicated only minor movement of nitrates downward in the soil. Research is underway to convert animal wastes to useful products. Returning manure to the land as fertilizer requires investigation, particularly the effect of heavy and frequent loading. Data are needed to develop limits for a wide range of crop plants.

Plant breeders of fruits and vegetables are selecting for factors that will reduce processing wastes. For example, new tomato varieties developed for mechanical harvesting have less processing waste. By processing tomatoes in the field with portable equipment, processing wastes can be left on the soil for recycling after harvest is completed. Many processing byproducts can be economically recovered and directed to other uses.

Cycling of organic matter in soil produces byproducts that may help control plant disease organisms. Thus, recycling of crop residues may serve a dual purpose.

Processing wastes, such as corncobs, grain straw, rice hulls, bagasse, and beet pulp, have been tested for disposal on land. The maximum amounts that can be disposed of without injury to a succeeding crop need to be determined for various soil types. Cultural practices may facilitate degradation.

Funds (in millions of dollars) expended by USDA for solid waste research during fiscal year 1969–71 are as follows.

1969	*1970*	*1971*
1.42	1.65	2.20

Department of Commerce

DOC is studying the degradation of polymers, corrosion of metals in natural environments, and the chemical analysis of metal mixtures that are potentially important to the design of recycling schemes.

Funds (in millions of dollars) expended by DOC for solid waste research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.10	0.20	0.20

Department of Defense

DOD is studying improved methods for disposal of such pollutants as deteriorated explosives and explosive-contaminated waste from munitions plants. A new type of incinerator is being developed using sand to dilute the explosive contaminant of waste material and to absorb any small explosions that may occur during incineration. Improved chemical methods of explosive disposal and lead azide degradation are being studied.

Funds (in millions of dollars) expended by DOD for solid waste research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0	0.10	0.20

Department of the Interior

Junked cars are a problem of major importance. During 1969, 7 million cars were scrapped in the United States, and about a 20 million backlog still awaits scrapping. The organic nonferrous constituents are most easily removed by incineration. Intensive investigation is underway on the recovery of individual nonferrous components. A major potential use for auto scrap is as a reductant for nonmagnetic iron ore. A method has been developed for the destructive distillation of tires to produce gaseous, liquid, and solid fractions, all of which are marketable. A pilot plant for such an operation has been constructed. Attention is being given to finding other uses for both the organic and ferrous fractions of junked cars.

Urban refuse collected by municipalities totals about 1 ton per capita per year. This refuse includes about 11 million tons of ferrous scrap, 1 million tons of nonferrous metal, and 15 million tons of glass, among other materials. A successful process has been developed whereby incinerator residues are separated into iron concentrates, clean nonferrous composites, clear and colored glass fractions, and fine carbonaceous ash.

Waste plastics can be converted by pyrolysis to gases, oils, and char. Additional improvements are

needed in the separation process and in conversion to use products.

During the past 30 years, over 23 billion tons of solid wastes have been generated in the United States by mineral and fossil fuel mining, milling, and processing. Over 7,000 square miles of land surface are essentially useless because of these barren waste piles. They are potential air and water pollutants. Stabilization of the waste piles to minimize pollution of other media offers the only practical solution. Chemical stabilization is possible, but vegetative stabilization is more attractive and promising. Some mineral wastes can be recycled. Additional research is needed on revegetation of waste piles and on utilization of certain fractions that are now wasted. Particularly valuable are nonferrous metals such as titanium.

Funds (in millions of dollars) expended by DOI for solid waste research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
4.40	4.90	4.59

Department of Transportation

DOT supports specific studies through the Federal Highway Administration with the specific objective of utilizing solid waste materials, such as fly ash, as constituents of highway construction materials, and possible recycling of highway-generated litter.

Funds (in millions of dollars) expended by DOT for solid waste studies during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.01	0.01	0.01

Environmental Protection Agency

Of the approximately 20,000 land disposal sites in the United States, less than 6 percent meet minimal criteria for sanitary landfills. Projects that affect land esthetics or improve its use are considered in this program. The purpose of R. & D. is to increase land value after its use as a sanitary landfill. Feasibility has been demonstrated for use of abandoned strip mines for sanitary landfills and for use of sanitary landfill to prevent erosion. Above grade sanitary landfills can be developed into recreational and other public use sites.

Projects are being conducted to improve the technology of recycling wastes and disposing of hazardous materials. The Resource Recovery Act of 1970 calls for four basic tasks: (1) Means of recovering materials and energy from solid waste, recommended use of recovered material or energy, identification of potential markets, and the effect of the recovered product on these markets; (2) changes in current product characteristics and production and packaging which would reduce the amount of solid waste; (3) methods of collection, separation, and containerization which will encourage efficient utilization of facilities and contribute to more effective programs of reduction, reuse, or disposal of wastes; and (4) alternative methods of stimulating recycling. As a part of the effort on waste disposal, a national disposal sites plan will be developed in 2 years to accomplish the storage and disposal of hazardous wastes.

Funds (in millions of dollars) expended by EPA for solid waste research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
8.19	8.99	11.40

National Science Foundation

NSF is involved in systems studies of solid waste disposal. Emphasis is placed on benefit-cost models of waste disposal systems and disposal of household wastes.

Funds (in millions of dollars) expended by NSF for solid waste research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.10	0.30	0.45

Tennessee Valley Authority

TVA does not expend funds for R. & D. in solid waste disposal. They do, however, cooperate closely with other agencies.

Following initial studies by TVA in the early sixties, the U.S. Public Health Service, in cooperation with TVA and Johnson City, Tenn., built a demonstration compost plant for treatment of municipal garbage, refuse, and sewage sludge. TVA now operates this plant for EPA on a reimbursable basis. Results from the operation of this plant have included: (1) An economic evaluation of plant operations for windrow composting as a method of disposal of solid wastes, (2) development of windrow design and composting time, (3) determination of pathogen survival in composted refuse-sludge mixtures, and (4) demonstration of the uses of compost.

RADIATION

Radioactive wastes are a land pollutant of considerable significance. The R. & D. underway by AEC and EPA as it relates to land quality is discussed fully in the chapter on special studies.

THERMAL

Research devoted to thermal pollution of land could not be separated from other thermal pollution studies. Consequently, there can be no discussion or fiscal breakdown for the research being conducted. It is recognized, however, that much of the basic research being done on heat transfer by NASA, AEC, USGS, TVA, Office of Saline Waters, and other Federal agencies could be applied to thermal pollution problems on land.

OTHER (UNCLASSIFIED) LAND QUALITY RESEARCH

Department of Agriculture

Research on several programs affecting land quality could not reasonably be classified elsewhere. These include studies to develop methods for controlling wind erosion by agricultural management practices, vegetative cover crops, and tree or crop barriers. Research is also underway to determine the effects of various pollutants on manmade structures and devices, for example the effects of siltation on dams and reservoir capacity.

Funds (in millions of dollars) expended by USDA for other (unclassified) studies during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
1.32	1.32	1.50

National Science Foundation

The research involves investigations of the breakdown of materials such as lignins and the fixation of various chemicals through the metabolism of microorganisms. Fixation studies have dealt particularly with iron, nitrogen, phosphate, and cyanide compounds. An understanding of biological processes in the breakdown of chemical compounds or the metabolic uptake of chemical compounds is critical to the more pragmatic investigations of pollution problems such as those resulting from industrial, animal, and human wastes.

Funds (in millions of dollars) expended by NSF for other (unclassified) land quality research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.60	0.59	0.69

Understanding, Describing, and Predicting the Environment

Funding of R. & D. pertaining to understanding, describing, and predicting the environment for fiscal years 1969, 1970, and 1971 is reported in table 6 (p. 146).

ECOLOGY AND RELATED RESEARCH

Corps of Engineers

Terrestrial and marine ecological systems of various geographic regions are investigated to determine the impact of engineering works and to develop technology and methodology for minimizing environmental damage but permitting national economic growth.

Biological and ecological research will provide an improved understanding of the effects of CE's activities upon the total environment of coastal areas, especially the vast complex of highly sophisticated and intricately interrelated ecological systems that provide benefits to man in the form of harvestable fishery resources and recreational opportunities.

Studies are carried out on water quality in reservoir releases and impoundments. Fisheries engineering investigations are undertaken to fill voids in fisheries information needed for water resource projects. This program is aimed at improving the efficiency of fish collection and passage systems at existing and new dams, to learn more about the response of fish to changed conditions.

Increased flow of water from the Chesapeake Bay to Delaware Bay resulting from the channel enlargement has raised ecological questions that are under study. The Chesapeake Bay Basin Study was funded for $1.3 million for fiscal year 1971.

Ecological studies are underway on the effects of offshore engineering works and coastal works, the dynamics of inlets and estuaries, and special studies on the Louisiana coast, New York Bight and offshore dumping, the Tennessee-Tombigee Waterway, pollution of the Texas gulf coast, a study of the Northeastern United States water supply, the North Atlantic regional water resources, a special study of the south end of Lake Michigan, and a San Francisco Bay and Sacramento-San Joaquin Delta waste water management investigation.

Funds (in millions of dollars) expended by CE on ecology and related research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
3.30	4.20	5.80

Department of Agriculture

The USDA ecological and environmental research defines, measures, and interprets ecological relationships important to environmental quality and human welfare for many forest, range, and wildland vegetational types throughout the United States. Much of the research seeks to establish the structure, development, and functioning of forest and range ecosystems as a basis for formulating management principles and cultural practices. Research ranges from determining the biological bases of productivity and the nutrient and energy relationships in forests and grasslands to the role of fire in the origin and perpetuation of vegetational types and the stability of wildland ecosystems under recreational use. Other research explores the autecology of forest and range species, for example, the silvical characteristics, reproduction, and growth of important forest tree species, the ecology of insects and diseases as a basis

for control of pests, the ecology of rangeland grasses, forage, and brush, and ecological principles for rehabilitation of eroded lands. Results of this research are being applied in the management of forests and grasslands and in the development of criteria and methods to preserve fragile ecosystems and reverse deterioration on abused sites. However, the structure and responses to alteration of many ecosystems are poorly understood. Management principles for preserving and improving the environment while supplying human needs are correspondingly tenuous.

Much research is needed to clarify interrelationships among native and introduced plants, animals, birds, insects, fungi, and micro-organisms. These interrelationships are multitudinous and complex and are made more so by differences among ecosystems and differential response to environmental factors such as wind, fire, temperature, precipitation, and man's activities.

Funds (in millions of dollars) expended by USDA for ecology and related research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
3.81	4.17	6.48

Department of Defense

A study defining the environmental factors of world desert areas has been completed and studies on the origin, distribution, frequency, and duration of sand and dust storms have been initiated. Terrain design criteria have been developed. Studies of the effects of chemical testing upon the ecology of regions adjacent to testing sites have been conducted for several years. Ecological baseline data have been gathered on areas in Maryland and Utah.

Short-range plans are to continue studies at the current level. Long-range plans depend upon the results of current studies, the level of testing necessitated in the future, and requirements for development of area environmental studies.

Funds (in millions of dollars) expended by DOD for ecology and related research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.40	0.70	0.50

Department of the Interior

The DOI's Bureau of Reclamation supports research on the effects of water projects and water management operations on the overall environment and ecology of an area, to provide information that can be used to structure the projects in ways to minimize deleterious effects and maximize enhancement effects. Preproject ecological and environmental studies are made in typical areas. Studies are conducted for periods sufficient to establish the effects that have been created by the project. The program includes design and field-response studies of esthetically more pleasing transmission facilities and locations for electric power facilities to provide much more acceptable structures and good public acceptance of the structures. It is planned to evaluate one type of fish's protective facility for its effectiveness in keeping fish out of an outlet works. Also, studies of environmental effects of waste water treatment facilities will be made to evaluate the impact of projects and to develop guidelines for future treatment projects. In addition, a research contract is underway to evaluate the ecological and environmental aspects of water resource planning. Other studies are planned to expand and to test the new value systems and criteria expected to result from this contract.

Funds (in millions of dollars) expended by DOI for ecology and related research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
4.10	4.00	6.90

National Science Foundation

Ecology research is supported in the General Ecology (GE) and Ecosystems Analysis Programs, (EAP), formerly the Environmental Biology Program, (EBP), under which support for the International Biological Program (IBP) was included in fiscal year 1969. In fiscal year 1970, the EAP was initiated to handle the IBP, which received a considerable fund increase. Research under the IBP includes the analysis of ecosystems studies that are conducted under biome projects. At present, research is being conducted in the various biomes: Grasslands, desert, deciduous forest, coniferous forest, and the wet tundra in Alaska. This research will contribute to the understanding of how ecological systems operate to both short-term and long-term processes. Systems disturbed by man to varying degrees are included. Several other areas are being studied as integrated research projects: The origin and structure of ecosystems with several subprograms including Hawaii terrestrial biology; the conservation of ecosystems; biological control; and the biological production in upwelling ecosystems and marine mammals. Research results will provide further understanding of the biological processes in these various areas.

The ecosystem analysis program also supports various studies on nutrient cycling in watersheds, research on freshwater and thermal springs ecosystems, and on wet and dry tropical forest ecosystems.

Research in general ecology concerns small ecosystem studies, structure and dynamics of communities and populations, paleoecology, biogeochemistry, ecophysiology, limnology, plant and animal ecology, host parasite relationships, and behavior and orientation. Research training grants in ecology, as well as operational support of inland field stations, phytotrons, and biotrons, are funded.

Systematic biology projects supported by the NSF include studies of various organisms under diverse ecological conditions. Geography, ecologic and seasonal distribution, life histories, and habitats are considered. A better understanding of evolutionary relationships may produce greater understanding of interspecific competition for limited ecological niche space.

Psychobiology research in this category includes behavior and ecology of various animals and the effect of the environment (natural wild conditions) on brain and behavior of rodents. Thermal adaptation of certain animals is studied, as well as research on migratory Atlantic salmon and American eels to explain the spectacular homing migration.

Research conducted under the research applied to national needs (RANN) program includes projects which are establishing environmental baseline data for broad ecosystem studies of specific regions such as the Chesapeake Bay. Research in progress includes projects concerned with environmental systems in the Tennessee River Valley, the Lake Tahoe area of California, and the Big Sky Region of Montana. The projects supported under the RANN program range in geographic size from regional to local.

The engineering sciences support theoretical and computational investigations of aspects of on-line direct digital control of reaction and environmental systems. Research is conducted on water flow, water tables, and hydrodynamics of watershed flow, ground water seepage problems, and pressure fluctuations in the vicinity of dams.

A theoretical study of the coastal boundary layers in a large lake, as well as the dynamics of ice-covered streams, and engineering and economic aspects of large continental droughts are under investigation.

Funds (in millions of dollars) expended by NSF for ecology and related research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
10.80	12.01	14.32

Smithsonian Institution

Biological and physical studies are carried out in collaborative, integrated research projects that will permit the evaluation, and ultimately the prediction, of environmental change.

The SI is using its large collections of plants and animals of the world, with detailed distribution and abundance data as a basis for an effective environmental monitoring system. The programs underway include: The Museum of Natural History develops critical environmental base line data on the abundance and distribution of plants and animals in relation to modification of the environment by man, and identifies bioassay and bioindicator organisms for monitoring the environment. The National Zoological Park carries out research on breeding and preservation of rare and endangered species of animals, and research on reproductive physiology and behavior of various animals. The Smithsonian Tropical Research Institute studies the abundance, distribution, and adaptations of tropical, terrestrial and marine plants and animals and studies effects of man-made change, effects of oil spills, and potential effects of a sea-level canal. The Radiation Biology Laboratory studies regulatory and other effects of light cycles on growth and development of organisms (primary productivity), photosynthesis, and biochemical and periodic response to light, and measures solar radiation. The Office of Environmental Sciences studies ecological consequences of man's technological developments on the environment and biological organisms, and ecosystem and community action study of a watershed for planning and predicting development of a megalopolis, and cooperates with and assists international programs and explorations. It also studies pollution problems and maintains sorting centers for marine biological organisms.

Funds (in millions of dollars) expended by SI for the ecology and related research during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
2.90	6.70	7.50

ENVIRONMENTAL OBSERVATION AND MEASUREMENT TO DESCRIBE AND PREDICT WEATHER AND OCEAN ACTIVITY

Corps of Engineers

The CE studies wind-wave relationships, wave activities, storms, general hydrology, and streamflow,

and rainfall data as they affect design criteria and construction technology in the coastal zone and inland.

The wind-wave action in coastal waters is studied to gain an improved understanding of the characteristics of ocean surface wind waves, their generation, propagation, transformation, breaking, and action on shores and shore protection. Long period waves and surges are studied to provide an improved understanding of the characteristics of long waves, particularly seiches, storm and hurricane surge, and tsunamis. In storm studies, data are accumulated on the most important past and current storms to evaluate flood-producing potentialities of river basins as related to the accomplishment of the civil works mission. General hydrologic studies include hydrologic analysis of rainfall-runoff relationships, snowmelt studies, flood forecasting, analysis of past floods, infiltration indices, unit hydrographs, development of flood hydrographs, and other studies of related hydrologic nature.

The research is conducted to gain an improved understanding of the processes involved in the interaction of the natural shore with the wind, wave, tide, current, and surge forces imposed upon it; and the reaction of the shore and shoreline to these forces and processes.

Data are obtained on environmental factors related to coastal engineering. This includes waves, water levels (with regard to storm surges), littoral materials on the beaches, suitable sand sources for beach replenishment, and rates of littoral material movement, quantity and characteristics of material made available to the shore area (whether by streams or shore or bluff erosion), and the economic life of various construction materials.

Assessment of beach and shore erosion problems is being made to appreciate the Nation's erosion problems considered in conjunction with economic, industrial, recreational, agricultural, navigational, demographic, ecological, and other relevant factors.

Funds (in millions of dollars) expended by CE for environmental observation and measurement to describe and predict weather and ocean activity during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
2.00	2.30	2.40

Department of Agriculture

Objectives of USDA's research are (1) to measure, interpret, and develop prediction methods for the effects of weather on forest fire danger and fire behavior and (2) to compile, interpret, standardize, and summarize climatological data correlated with phenological information for agricultural use. Relationships between weather and fire are incorporated into fire danger indexes and used to predict forest fire behavior. Weather data are used to derive probabilities of rainfall amounts, wet-dry days, and growing degree days for correlation with crop growth stages and maturation.

Wind flow in mountainous terrain critically affects fire danger and behavior, but measurement, correlation, and prediction methods remain to be developed. New techniques of analysis for spatial and temporal distribution of climatic elements are being devised, as well as models to incorporate climatic information into agricultural decisionmaking and means to delineate atmospheric conditions conducive to air pollution.

Funds (in millions of dollars) expended by USDA for environmental observation and measurement to describe and predict weather and ocean activity during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
0.90	1.00	1.02

Department of Commerce

Atmospheric environment. The National Oceanic and Atmospheric Administration (NOAA) in support of its environmental services and research missions conducts a program of research that includes nearly all aspects of the atmospheric sciences. The research is conducted primarily through NOAA's Environmental Data Service, Environmental Research Laboratories, National Weather Service, and National Environmental Satellite Service.

The world weather program R. & D. activities planned by NOAA focus on systems design and technological developments for both the global atmospheric research program (GARP) and the World Weather Watch. GARP is an international effort designed to further the understanding of atmospheric processes necessary to develop capability in long-range weather prediction. The program consists of two major parts—(1) theoretical research on atmospheric physical processes and (2) supporting field experiments to provide the necessary understanding of how energy is exchanged between the atmosphere and oceans at the air-sea interface. The understanding of how small-scale processes can be incorporated in the terms of large-scale measurements of the atmosphere is essential in the development of the capability for long-range weather prediction.

The Geophysical Fluid Dynamics Laboratory is conducting research in theoretical modeling of atmospheric and oceanic processes and dynamics, and in computational simulation of their characteristic behavior and phenomena. The range of predictability of midlatitude, large-scale storms beyond one week will be extended. Global prediction experiments to study the coupling between the hemispheric circulations and the role of the tropics will be performed. Increased sophistication of models and their growing fidelity and similitude to the actual atmosphere and oceans have indicated several potential application areas including long-range weather and oceanic prediction, the large-scale, long-term dispersion of pollutants in the atmosphere and the oceans, and an assessment of the feasibility of intentional modification of climate and its inadvertent modification due to human activity.

Research on hurricanes and other tropical circulations, and severe local storms, such as thunderstorms, tornadoes, and associated phenomena, is conducted to acquire greater knowledge of these storms for developing techniques of detecting, forecasting, and modifying. Studies of tropical cyclone genesis and maintenance will be accelerated through development of improved dynamical-numerical models of tropical circulations and hurricanes.

Integrated field experiments employing several newly developed remote sensing techniques will receive increasing attention during fiscal year 1972. The International Field Year on the Great Lakes (IFYGL) will provide an excellent opportunity to compare atmospheric data taken by various remote sensing and standard *in situ* techniques. The lead agency responsibilities were assumed by NOAA concurrent with the recent transfer of the Lake Survey to NOAA from the CE. The IFYGL which is a joint Canadian-U.S. program for increasing our understanding of the water problems of Lake Ontario and its basin, includes four projects: Lake meteorology, energy balance, terrestrial water balance, and water movement.

R. & D. at the National Meteorological Center is primarily directed toward improving the short, extended and long-range forecast products. The two main activities concern numerical weather prediction that is a deterministic approach through physical realism of mathematical models, and long-range prediction, that is a systematic application of physical and statistical methods and models.

The climatological research program will continue the development of an environmental data index (ENDEX) to facilitate ready access to available climatic and other data. Studies of long-term changes in national and world climate will continue by using any newly acquired measurements from global benchmark stations. Satellite-based weather observations will be related to ground truth data in an effort to optimize eventual applications of earth resources satellite information.

Upper atmosphere and space.—NOAA conducts a research program in aeronomy to increase the understanding of the solar-terrestrial environment, and to develop techniques for the forecasting of solar disturbances and their subsequent effects on the earth environment. Investigations into the ionospheric physics will use new approaches and exploit recent significant results.

In geomagnetism, a study of the atmospheric current systems resulting from tidal effects on the atmosphere in the presence of the geomagnetic field will be initiated.

Theoretical and experimental studies concerning the transport of energy released by the sun and propagated through the interplanetary medium to the vicinity of the earth will continue. Theoretical models of energy transport will be tested with data obtained from new experiments.

Environmental satellite research.—In the environmental satellite program, emphasis on deriving and using quantitative information from data obtained by satellites will continue. Operational procedures for deriving winds from time-lapse cloud motion observations will be further developed and tested in preparation for the Geostationary Operational Environmental Satellite (GOES) system to be established late in fiscal year 1972. New projects to be undertaken will emphasize the application of satellite technology to improved services and support of marine, hydrology, and space disturbances programs. An increased effort is planned for 1972 in the development of satellite sensors needed to support geophysical monitoring for climate change, and sensors to obtain measurements required in the marine environmental prediction programs.

Marine environment.—To provide a proper technological base for increased marine weather activities, a broad R. & D. program in marine weather has been conducted and a systems approach developed. Investigations of ship density have shown advantages from instrumenting additional merchant ships. Sensors capable of continuous operation in the harsh marine environment are being developed, particularly for use on buoys.

Special attention has been given to the development of improved techniques for forecasting wave

heights in the open ocean, coastal wave heights and breakers, and waves on the Great Lakes.

Oceanographic programs involve studies of the influences and interactions of the oceans with their physical environment, study of the Gulf Stream, extending the marine services and applying knowledge gained to national needs for improvement of oceanographic techniques and instrumentation.

An important factor, both to meteorology and oceanography, is the sea-air interaction between the oceans and atmosphere, involving a study of exchange processes of heat, moisture, momentum, and mass. The program consists of developing better instruments and better mathematical models.

The Great Lakes research is aimed at a better understanding of the natural environment in the Great Lakes and connecting channels and at forecasting the effects of manmade changes. The program provides information to be used in optimum management and development of water and land-related resources. The program includes studies on water motion, water characteristics, water quality, and ice and snow.

National data buoy development project.—This project was established to carry out the development of a system of automatic ocean buoys for obtaining oceanic and atmospheric data. While measurements of the oceans are available from satellites, ships, and aircraft, the need for more detailed data on environmental conditions over vast uninhabited marine areas has long been recognized. A network of automatic buoys throughout the ocean is a logical method to bridge this information gap. The data buoy project is developing and deploying a network of pilot oceanographic and marine meteorological data collection buoys preparatory to a future decision to deploy an operational system. Central to the task is the compilation and analysis of interagency and extragovernmental requirements, including environmental studies; the analysis of costs, benefits and tradeoffs; and the development of improved equipment for reliable, accurate, unmanned buoy operation.

Funds (in millions of dollars) expended by DOC on environmental observation and measurement to describe and predict weather and ocean activity during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
19.70	22.90	35.50

Department of Defense

The DOD must at all times have the best weather information technologically feasible to obtain. To provide this constantly improving service, the Air Force supports research efforts in the areas of weather forecasting and the development of improved sensors. Satellite weather forecasting is being investigated to obtain an automatic and quick response forecast system. Development of new instrumentation and techniques to provide routine measurement of atmospheric parameters is being employed to increase the accuracy of prediction by improving the quality of the data base. Sensors are being developed to provide operational lightning warning. The Air Force operates the national clear air turbulence program and shares the national responsibility for hurricane reconnaissance. The Army determines the effects of atmospheric conditions upon transport, diffusion and the trajectory of aerosols, and detects contaminated air. The Navy develops and tests methods and equipment to improve efficiency and capability to collect oceanographic environmental data; increases the accuracy of oceanographic predictions which affect Naval operations; provides new means for data compilation and presentation to permit earlier and increased usage of data collected. The hydrographic survey and charting system increases the capability of collection of near-shore hydrographic data. The funds for oceanographic instrumentation and equipment have been transferred to NOAA.

A future project will be the bottom topographic survey system that will greatly increase capability for collection of bathymetric data from the deep ocean. Satellite technology is also being developed for improved oceanographic surveys.

Funds (in millions of dollars) expended by DOD on environmental observation and measurement to describe and predict weather and ocean activity during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
8.59	13.87	13.41

Department of the Interior

The U.S. Geological Survey (USGS) conducts research and develops opeational techniques for calculating the circulation of water and associated solids and solutes in estuary and lagoon waters from tide-stage and other data. USGS makes geologic and hydraulic studies of sediment movement into and in estuaries. In cooperation with States and other agencies, it maintains programs of measuring the amount and rates of fresh-water inflow and water-quality parameters. It also carries on an expanding program of monitoring the background water quality within estuaries and similar coastal waters.

USGS specifies equipment and techniques for preventing and controlling the pollution of ocean waters which can result from mineral operations.

Funds (in millions of dollars) expended by USGS on environmental observation and measurement to describe and predict ocean activity during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
1.69	1.98	2.09

National Aeronautics and Space Administration

NASA has an extensive meteorological survey program in cooperation with other Government agencies using earth orbiting and synchronous satellites which give continuous synoptic coverage on a hemispheric scale. These surveys show day and night cloud cover, distribution of surface temperature, circulation, turbulence of the atmosphere, some wind velocity and direction, fronts, and jet streams. Studies are also being carried out on gravitational stability of large gas clouds.

NASA's meteorological program (MP) has provided the global monitoring capability that is essential to increasing the accuracy and extending the time range and scope of weather predictions. MP also provides the basis for developing tools for assessing the effects of man's pollution of the atmosphere on the quality of our environment. The National Operational Meteorological Satellite System (NOMSS) developed and launched by NASA, supports the U.S. weather services. A development program is expanding the observational range and improving its coverage, accuracy, and reliability. Satellites of the TIROS, TOS, Improved TOS, Nimbus, and ATS families have provided capabilities for observing weather conditions and preparation of severe weather warnings, affecting the entire world.

In the earth resources survey program, multispectral sensing is being developed and tested by using aircraft, preliminary to global satellite coverage. This development gives great promise to determining vertical temperature, moisture, pressure, and CO_2 profiles, improved cloud cover and atmospheric circulation; and detailed mapping of air pollution. The budget figures include supporting research and technology, spacecraft and hardware, but not launch vehicle costs.

The NASA aeronomy program includes studies of the mesosphere and thermosphere, along with such phenomena as airglow, aurorae, magnetic fields, and current systems in the ionosphere. Altitudes of interest range from about 50 to about 1,000 kilometers. The experimental program employs sounding rocket and satellite measurements. The program includes Tiros satellites, Nimbus satellites, and the Synchronous meteorological satellite. None of the costs of spacecraft, launch vehicles, or ground operations are included. The total costs are fiscal year 1969, $60.30 million, fiscal year 1970, $53.60 million, and fiscal year 1971, $60.10 million. The cost of supporting research and technology and experiments is reported below.

Funds (in millions of dollars) expended by NASA for environmental observation and measurement to describe and predict weather and ocean activity during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
30.80	30.00	31.40

National Science Foundation

The goal of the NSF program in oceanographic research activities is to gain a better understanding of the sea and associated phenomena necessary to develop and use the vast resources of the sea. The physical oceanography program supports study of ocean-atmospheric interactions including air-sea exchange of CO_2 and O_2 and its dependence upon currents, upwelling, photosynthesis, and so forth. Other studies include ocean currents, continental shelf circulation, and upwelling processes.

The chemical oceanography program supports geochemical studies of the ocean and development of new techniques for *in situ* measurements of metals in the ocean. The Geochemical Oceans Sections Study measures oceanic constituents at all depths in the Arctic and Antarctic areas to study ocean mixing and organic productivity.

Investigations of the biological components, together with physical environmental studies, are providing greater understanding of how the ocean functions as an ecosystem. Knowledge at this level of organization is vital, if we are to use the resources of the ocean wisely and to understand the effect of human activities on this environment.

Research on the process and phenomena taking place in the ocean environment includes studies of the dynamics of the water masses including day-by-day and year-by-year changes in temperatures, current flow, etc. The past history of the oceans, which is recorded in the ocean sediments and deep waters, gives clues to the changes that have occurred and are occurring. Part of the Foundation support

of oceanographic research is devoted to the analysis of these deep waters and sediments.

The NSF also gives emphasis to oceanographic research investigations concerned with the modes and energy content of internal motions of the ocean and to studies aimed at gaining a better understanding of the important exchanges of energy and material between the ocean and the atmosphere.

NSF is designated as lead agency for the United States involvement in the International Decade of Ocean Exploration, (IDOE).

IDOE is an effort in which the United States and other participating nations will apply their combined resources to expand their knowledge of the earth's marine environment for their mutual benefit. The IDOE is an outgrowth of the realization that the future well-being of mankind will depend, to a large extent, on our ability to expand the uses we make of the oceans. At the same time we must find ways to protect the marine environment from the degradation which modern technology has already wrought.

The program objectives for IDOE are to assess and monitor the ocean environment, improve environmental forecasting, expand seabed assessment activities, improve worldwide marine data exchange, and increase opportunities for international sharing of costs for ocean exploration. In achieving these objectives, NSF utilizes the capabilities of academic institutions, other Federal agencies, and other qualified organizations.

The objective of the Foundation's atmospheric sciences research program is the building of a base of new knowledge about natural phenomena and fundamental processes taking place in the atmosphere. The results of this research will help man in his efforts to forecast the state of the atmosphere and ionosphere in advance and to eventually exercise some degree of control over atmospheric processes and weather. Atmospheric science research is concerned with all aspects of the character and variations of solar energy and its transmission through interplanetary space, reaction with ionized and neutral gases of the earth's atmosphere, and the atmospheric processes near and at the surface of the earth. Work underway in the global atmospheric research program (GARP) and the weather modification program benefits from the investigations supported by scientific research project support. The Foundation-supported National Center for Atmospheric Research (NCAR) is a major facility that enhances the national capability for both fundamental and applied atmospheric research. NCAR has built a research program that covers the full spectrum of phenomena that affect the earth's atmosphere and which constitutes a major part of the U.S. effort in atmospheric research.

The objectives of this National Research Center are to: (a) Improve our knowledge of the behavior of global atmospheric circulation to the point of being able to predict the large-scale features of the weather a week or more in advance. (b) Ascertain the lifetimes of pollutants to the point of being able to understand adequately both their local and worldwide effects. (c) Develop realistic mathematical models of convective clouds to the point of being able to predict the intensity of cloud buildup and the outcome of various weather modification techniques applied to the clouds. (d) Provide leadership in the atmospheric sciences including the provision of training opportunities for young scientists.

Funds (in millions of dollars) expended by NSF for environmental observation and measurement to describe and predict weather and ocean activity during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
10.01	11.70	17.00

Smithsonian Institution

The Smithsonian Astrophysical Observatory (SAO) measures the solar radiation, the atmosphere composition and changes, the heat balance and heating of the earth. Continual measurement is required since the atmosphere is constantly changing from the influence of the earth beneath it and the solar radiation above it, with resultant effects on the earth's climate, both globally and locally.

The SAO uses the same techniques developed for measuring satellite orbits by using its worldwide observing stations to monitor temperature and density variations in the upper atmosphere caused by solar activity. SAO also monitors the atmospheric composition through laser and photometric measurements of pollutants, such as water vapor and dust.

Funds (in millions of dollars) expended by SI for environmental observation and measurement to describe and predict weather and ocean activity during fiscal year 1969–71 are as follows:

1969	*1970*	*1971*
1.00	0.40	0.40

IMPACT OF ENVIRONMENT ON MAN

Corps of Engineers

The CE investigates environmental values as they affect the development of water resources and their

interrelationships with man. This includes recreation demand and esthetic evaluation. Systems analysis and operations research modeling techniques were developed and mathematical models were used to evaluate (1) the demand for various potential water resource uses to meet man's needs and (2) the relationship between man's needs and impact on the ecological systems.

Funds (in millions of dollars) expended by CE for impact of environment on man during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0.20	0.20	0.20

Department of Health, Education, and Welfare

The mission of HEW's Bureau of Community Environmental Management (BCEM) is the protection of health and safety of residents of urban, suburban, and rural settlements in specific human ecological areas. The major focus is the development of means of maintaining or changing both the man-built physical surroundings and the attitudes and behaviors of social environment that are appropriate to the healthful and safe use of built environment.

The BCEM has programs in three areas: (1) In human ecology research designed to ascertain the dynamics of health ecosystems, including both the physical and social environmental factors that affect changes in health status and morale. Such studies include investigation of stressors in both the physical surroundings and social environment of human settlements, under different climatic conditions and under land use and population densities ranging from rural to congested urban. (2) Basic health and safety criteria research for standards of design, maintenance, occupancy, and use of residential and community recreational environments, followed by evaluative health and safety research of developments built and used under the guidance of such standards. (3) Applied and evaluation research and development of community health environmental management systems, including public administration process and procedures, legal relationships and responsibilities, and community organization and health education techniques, which lead to better private and public management as measured by health status change in evaluation of demonstration programs.

The National Institute of Environmental Health Science supports research on the phenomena associated with the source, distribution, mode of entry, and the effects of environmental agents on biological systems through grants to universities, research institutions, and other public or private nonprofit institutions.

This activity supports the in-house research programs, environmental health sciences at the National Environmental Health Science Center in the Research Triangle Park. Included are research efforts in cell biology, pharmacology and toxicology, analytical and synthetic chemistry, biophysics and biomedical instrumentation, animal science and technology, pathologic psychology, epidemiology, biometry, epidemiologic pathology, and scientific information, as well as the supporting services for these laboratories and branches.

The carcinogenesis area of the National Cancer Institute bears responsibility for the planning, implementation and management of a coordinated research program on carcinogenesis by chemical and physical factors which it carries out both through a program of intramural research and through research contracts to universities and other research institutions. To meet this responsibility, it is necessary to devote a sizable portion of available resources to an attempt to identify those materials in man's environment which produce carcinogenic effects in animals after prolonged exposure.

The materials receiving greatest attention in the carcinogenesis bioassay program, which have not been discussed under air or land quality, fall into the following categories: (a) Pharmaceutical agents; (b) industrial chemical; (c) food constituents, additives, and contaminants; (d) natural products, particularly mycotoxins; (e) metals and metalloorganic compounds; and (f) tobacco and related products. An attempt is being made to acquire information on usage and to determine the feasibility of creating an information system which will assist persons responsible for management of bioassay programs in making assessments of priority for testing.

Funds (in millions of dollars) expended by HEW on impact of environment on man during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
27.30	23.60	24.60

National Science Foundation

NSF's research includes social sciences research with projects in anthropology and archeology, and social psychology. The archaeological research is being conducted in diverse geographical locations to

provide a scientific study of material remains such as fossil relics, artifacts, and monuments which illustrate past human life and activities and culture. The results of the anthropological research will be related to changing environmental and ecological conditions. In the ecosystem analysis program of the International Biological Program, population genetics of a tribe of primitive Indians is being studied to determine questions of inbreeding levels, genetic drift, stabilizing selections, not susceptible to deterministic formulations.

Engineering research is involved with effects of such factors as urbanization, deforestation, and wind on the environment. Support has been given for projects involving a study on a hydrologic model for predicting the effects of urbanization, deforestation, and wind on the environment. This mathematical model will help appraise hydrologic changes, their magnitudes, effects, and possible remedial actions.

The RANN program is supporting the Oak Ridge National Laboratory to conduct research on the potential for genetic mutations in man resulting from the introduction of manmade chemicals into the environment. Several approaches are being developed for mass screening of mutations in man. Other studies will develop techniques for performing overall ecological evaluations of the environment, increasing public awareness of environmental quality, projecting the costs and consequences of alternate environmental policy actions, and development of a computer simulation model to predict the influences of alternate environmental policies in the Tennessee River Valley.

Funds (in millions of dollars) expended by NSF for impact of the environment on man during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
2.30	2.30	2.80

Smithsonian Institution

SI's research on the impact of the environment on man includes studies by the Museum of Natural History on anthropology research on effects of climatic changes on man both historical and present. The Center for the Study of Man is studying the effects of rapid environmental change resulting from urbanization, improved transportation, and so forth. The Museum of History and Technology is studying the effects of shelter, heating, and cooling man's environment. The Smithsonian research awards program is studying the mathematical modeling of environmental factors and environmental prediction and effects on man and adaptation of man. The Smithsonian foreign currency program includes studies on the impact of man's technology and destruction of natural environment on rural and urban communities, and unusually rapid modernization in developing countries.

Funds (in millions of dollars) expended by SI for impact of environment on man during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
1.70	2.00	2.30

LOCATING AND DESCRIBING NATURAL RESOURCES

Department of Agriculture

USDA's research encompasses development of techniques and accumulation of natural resource availability and planning data through remote sensing, high altitude photograph, and direct inventory. Objectives range from broad-based surveys and evaluations, such as land resources, land-use patterns, water requirements, future demands among competing uses, and land and water conservation and development alternatives, to development of methodology and inventories for specific resources or significant interrelationships. About half of the program consists of the Forest Survey that is a continuing inventory of the forests of the United States and of future timber needs and prospective supplies. Other programs include measurement of soil moisture, nutrient, and salinity conditions; snow accumulations on wildlands; rangeland productivity; forest fuel distributions; and detection and analysis of forest insect and disease outbreaks. Direct inventory methods can achieve good accuracy, but they are slow and expensive. High altitude photography, remote sensing, and computerization for rapid data reduction and analysis are new and developing fields. They show mueh promise but require much research for development of techniques, for feasibility of monitoring and surveillance activities, for timely availability, and recall and updating of information.

Funds (in millions of dollars) expended by USDA on impact of environment on man during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
4.74	5.31	5.87

Department of the Interior

DOI's scientific investigations are carried out by the Geological Survey on the origin, occurrence, and

distribution of fuel and nonfuel minerals and mineral raw materials in nature; the development and improvement of mineral exploration concepts and techniques for locating new deposits of minerals; and the evaluation of known and potential mineral resources of the Nation. This research is essential to the Federal Government in meeting its responsibilities for (1) assuring that adequate and dependable supplies of mineral raw materials are available to domestic consumers, (2) insuring the orderly and efficient development of domestic mineral resources with a minimal detrimental effect on the environment, and (3) judiciously managing the public lands and their contained resources.

Offshore geologic surveys are contributing to a planned long-term program that will result in regional geologic information and reconnaissance (small scale) geologic maps of significant parts of the U.S. continental margins and that ultimately will contribute geologic analyses and maps of the submerged continental margins. Such analyses help provide the necessary geologic data for managing resources in the public land and in producing geologic maps for all of the continental United States.

National land and mineral resources surveys include the nature and distribution of minerals and investigations of fundamental geologic, geochemical, and geophysical processes. Geologic maps are prepared at scales appropriate for appraisal of environmental properties of the land and for determination of its mineral resources.

The water resources investigations activity and the areal appraisal, special studies, and Federal water data coordination activity investigate and describe the location, distribution, quantity, quality, and movement of surface and underground water resources of the Nation. In addition to basic research on hydrologic principles and techniques of investigation and prediction, the program includes acquisition of data on streamflow and ground-water levels, coordination of Federal water-data acquisition, investigation of specific water problems (for example, floods, droughts, ground-water recharge), environmental quality effects and interactions between water, air, land, and ecological systems, and assistance to other agencies in the solution of specific mission-oriented water problems.

The Earth Resources Observation Systems (EROS) program includes: (1) Collection and processing of remote-sensing data of direct use in environmental research and action programs; (2) analysis of the data to develop new information to permit detection and monitoring of environmental status and change; (3) dissemination of this data and information to Government and private resource and environmental research and management groups; and (4) continuation of research, development, and further refinement of remote-sensing techniques, and of methods and equipment for extracting and interpreting such information.

The Office of Water Resources Research program sponsors research, and trains scientists in the fields of water resources which assures the Nation of a supply of water sufficient to meet its water supply requirements.

Assistance to States for institutes provides for specific grants for assistance in water resources research at one college or university in each State. Matching grants are also given to institutes and universities to carry out research in this field.

Water resources planning and engineering research involves water supply augmentation and conservation, water quality management and control, water quality management and protection, water resources planning, and engineering works.

Funds (in millions of dollars) expended by DOI for locating and describing natural resources during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
28.09	31.82	32.17

National Aeronautics and Space Administration

NASA's earth resources survey program is being developed to provide a global capability to survey and monitor the earth's resources, measure the changes in those resources, and provide continuous monitoring of the significant environmental and ecological relationships. Aircraft and manned space flight experiments have demonstrated the feasibility and economic and social value of remote sensing of the earth's forests, agriculture, water resources, oceans, geography, minerals, and even its atmosphere. The earth resources technology satellites (ERTS) currently being developed will demonstrate and test techniques for routine monitoring of resources and the environment from space. Data provided by the earth resources survey program can provide the means for the detection of air, water, and solid waste pollution, crop and forest degradation, and the occurrence and consequences of natural disasters.

The total NASA program for earth resources survey included the earth resources technology satellite, aircraft surveys, and the earth resources experiment

package for Skylab. The total cost is for fiscal year 1969, $13.90 million; for fiscal year 1970, $44.60 million; and for fiscal year 1971, $107.40 million including spacecraft and operations but not launch vehicles. The costs for experiments supporting research and technology, and data analysis are given below.

Funds (in millions of dollars) expended by NASA for locating and describing natural resources during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
11.10	40.10	71.10

National Science Foundation

NSF's seabed assessment activities under the International Decade of Ocean Exploration (IDOE) are directed to a goal of permitting better utilization of mineral resources on the seabed by acquiring needed knowledge of seabed topography, structure, dynamics, and mineral location. The data obtained will improve the management of resource development, identify hazardous geologic conditions, and assist in formulating policy for international discussions of the seabed and its resources.

Elucidation of the evolution and mineral potential of small ocean basins and selected wide continental margins are among the short-term IDOE objectives supported by studies initiated in fiscal year 1971. The main emphases of these studies are directed to the Gulf of Mexico, Caribbean and Bering Seas, and the continental margin of the eastern Atlantic.

The Foundation's ocean sediment coring program has as its objective the acquisition of samples through the sedimentary layer of the deep ocean basins to serve the advancement of marine geology and related geologic and geophysical sciences. From such samples, which have never before been available from depths below the sea floor, is derived knowledge that is necessary for our understanding of the structure and history of the crust of the earth.

The discoveries made upon a first examination of the cores, while still on board the drilling ship, have been beyond expectations. In addition to the first surprising discovery of petroleum in the deep sea floor, minerals such as native copper, zinc sulfide, and iron carbonate have been recovered off the continental slope of eastern North America.

NSF also supports basic research grants on description, biogeography, and ecology of various groups of flora and fauna, and some for hydrologic modeling or resource econometrics. None of these activities directly contribute to economic resource development.

Funds (in millions of dollars) expended by NSF for locating and describing natural resources during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
2.30	2.40	2.90

SURVEYS TO DESCRIBE THE PHYSICAL ENVIRONMENT

Department of Commerce

NOAA's marine geophysics program dealing with the liquid envelope and the earth below the oceans includes terrestrial magnetism, gravity, seismology, geological oceanography, and related sciences. The marine geophysical program is describing the marine environment in terms of various parameters that are of interest to the various scientific communities. Current geophysical research on the continental margins involves studies in morphology, structure, and sedimentary processes. Deep ocean basin research attempts to provide a basic understanding of the characteristics of the ocean crust and of the depositional and tectonic processes occurring in the deep ocean basin.

Research seismology attempts to improve understanding of the natural forces that generate earthquake mechanisms, and of the destructive power of earthquakes. Research is aimed toward basic knowledge of geophysics and tectonics of earthquakes and the physical structure of the earth. Instruments are deployed in areas of known seismic activity to monitor geophysical phenomena at the site. Specific studies are underway on the nature of the earth movement at the time of the earthquake and the relationship of this movement to tsunami generation. Efforts are being made to increase the value of seismic data by improving recording instruments, by increasing the accuracy of earthquake location determinations, and by developing more advanced data processing capabilities for including larger quantities of data in the analysis.

Funds (in millions of dollars) expended by DOC for survey to describe physical environment during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
1.90	1.90	2.00

Department of the Interior

The Geological Survey is studying special geologic hazards. This includes a major geological and geo-

physical program to discover what causes earthquakes and what can be done to decrease their dangers; an investigation of volcanic processes to provide basic data prerequisite to developing a predictive system; and engineering geologic studies providing information on foundation conditions, stability of slopes, drainage characteristics, and engineering properties of rocks and soils needed for land-use planning and construction in many areas.

Funds (in millions of dollars) expended for DOI for survey to describe physical environment during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
1.64	1.83	2.00

National Aeronautics and Space Administration

The NASA earth physics program includes studies to: (1) Apply geodetic satellite technology, precision satellite tracking techniques, and precision astronomical techniques to measurements of the dynamics of the solid earth and oceans; (2) establish marine geodetic control points; and (3) contribute to the objectives of the National geodetic satellite program with respect to accurate determination of the size and shape of the earth. The program includes the geodetic satellite program and a supporting research program to provide improved measuring techniques, a better knowledge of information requirements, and systems concepts to meet these requirements. The knowledge gained from these activities may contribute to the development of techniques for predicting earthquakes, volcano eruptions, and general oceanic circulation, and will facilitate the production of mapping of resources on the ocean floor.

Funds (in millions of dollars) expended by NASA for survey to describe physical environment during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
4.00	3.40	4.40

National Science Foundation

Geology research ranged widely from the study of the most ancient rocks and their fossils to the study of present processes of glaciation, river erosion, and sedimentation. Most of the projects are strongly field oriented, in contrast to the laboratory studies of geochemistry.

The past decade has seen a revolution in the science of geology. The concept of sea floor spreading and plate tectonics, barely thought of in 1960, is generally accepted as a reasonable theory, based on evidence largely obtained through studies of core samples collected under the ocean sediment coring program. Perhaps of even greater importance have been the concurrent development of the unifying concepts of sea-floor spreading and plate tectonics along with the critical need for information on and understanding of the balance of nature.

The discoveries made upon a first examination of the cores, while still on board the drilling ship, have been beyond expectations. The concept of sea-floor spreading has come to be generally regarded as valid. As a result of information obtained in analyzing the substance of the cores, other geologic facts of worldwide significance are becoming evident. For example, the Northwest Pacific appears to comprise a remnant of the oldest ocean yet extant; the Gulf of Mexico has been estimated to have remained an oceanic basin at least since early Cretaceous times (about 120 million years ago); blocks of continental crustal material appear to have foundered and sunk in the North Atlantic since Cretaceous times. In addition to the first surprising discovery of petroleum in the deep sea floor, minerals such as native copper, zinc sulfide, and iron carbonate have been recovered off the continental slope of eastern North America.

Funds (in millions of dollars) expended by NSF for survey to describe physical environment during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
1.00	2.75	7.00

Smithsonian Institution

The Smithsonian Astrophysical Observatory (SAO) is studying the extremely mobile earth's surface. Of special interest are the large surface blocks or plates whose interactions appear to be responsible for large earthquakes, mountain building, generation of tsunamis, and confinement of active volcanic activity to a few narrow belts. Thorough monitoring and understanding of these phenomena may lead to prediction of earthquakes.

The SAO is using the most precise laser and electronic techniques to monitor these geophysical changes, by observing the motions of artificial satellites in the earth's gravitational field. SAO is also pioneering in the development of more accurate measurement techniques.

Funds (in millions of dollars) expended by SI for surveys to describe physical environment during

fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0	0.20	0.20

WEATHER MODIFICATION

Department of Agriculture

Development of cloud-seeding techniques for suppressing lightning storms that produce forest fires is being done to reduce forest resource damage resulting from wildfire and to increase water yield from mountain watersheds, particularly in the growing season.

In the Forest Service Project Skyfire, field experiments are testing lightning suppression when a full storm system is heavily seeded. Research is conducted to improve seeding equipment, to develop a mechanism of lightning suppression through the depression of the sparking potential of supercooled water droplets by glaciation, and to identify the less common long-pulse lightning strike as the principal fire starter.

Future research is needed to improve the use of cloud seeding techniques and to develop computer models of cumulus convection as a basis for simulation experiments on lightning occurrence.

Funds (in millions of dollars) expended by USDA for weather modification during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0.44	0.45	0.52

Department of Commerce

Hurricane modification—Diagnostic studies by NOAA of the basic physical properties of the atmosphere that determine hurricane formation, movement, and dissipation are emphasized by using computer modeling techniques to examine basic concepts for hurricane modification. In Project Stormfury, jointly sponsored program by DOC (NOAA) and DOD (Navy), field experiments involved release of seeding material into hurricanes and associated clouds to assess effects on the wind velocity or the direction of storm movement or both.

Diagnostic studies of the basic physical properties of the atmosphere that determine hurricane formation, movements, and dissipation will be complemented by computer models. Studies will also be made concerning the feasibility of storm modification through the use of chemicals to retard evaporation from the surface of the ocean.

Studies also involve tropical cloud modification and effects of various methods of seeding on snowfall. Studies are underway on hail and lightning suppression and of inadvertent weather modification by man-made constituents especially carbon dioxide and water vapor.

The future program will aim at a full determination of procedures for manipulating mesoscale winter cloud systems, including mitigation of severe localized snowstorms, release of precipitation and lateration in mesoscale climate through cloud dissipation. Further studies of the influence of metropolitan areas on clouds and precipitation will be conducted.

Funds (in millions of dollars) expended by DOC for weather modification during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
1.30	1.40	1.40

Department of Defense

Operational techniques for modifying local weather conditions are required for use by the DOD. Theoretical, laboratory, and field studies are conducted to develop, refine, and verify realistic models simulating natural atmospheric processes and their modification. The models serve as a basis for designing operational modification systems without the need for extensive test programs for each potential application. Research is currently directed toward the development of techniques for suppressing dissipating warm and cold fog stratus clouds or both. The feasibility of producing large clearings in shallow warm fog and stratus layers by the down-wash mixing effect of a helicopter has been conclusively demonstrated. A numerical model of the dissipation of nonturbulent fog by hygroscopic particle seeding has been developed. Field experiments of the hygroscopic method have, however, emphasized the necessity of including the effects of turbulent diffusion in the model before the realistic potential of this modification technique can be assessed. Cold or supercooled fog consisting of liquid water droplets at below freezing temperatures is comparatively easy to dissipate by introducing a large number of ice crystals into the fog. Methods are being investigated for preventing high electrical fields within cumulus clouds to suppress lightning.

Funds (in millions of dollars) expended by DOD for weather modification during fiscal years 1969–71

are as follows:

1969	*1970*	*1971*
0.09	3.50	4.70

Department of the Interior

Precipitation modification.—The DOI's Bureau of Reclamation has started early preoperational projects in connection with the West Wide water planning studies. Pilot-type research projects are designed to be the last development phase before initial operations. The Colorado River Basin pilot project is seeding a large target area to provide sound scientific and engineering evaluations of precipitation increases over large areas by an operational-type application of developed cloud seeding techniques. The North Dakota pilot project is operationally testing seeding of groups of summer cumulus clouds and convective storms over western North Dakota.

Experimental research field activities are being carried out in nine States in the West by using aircraft and ground seeding. Research projects are underway to attempt to shift precipitation to other areas, on effects of seeding on clouds, particle growth, and cloud electrification.

Research programs underway include: Development of Techniques utilizing hydrologic parameters to evaluate precipitation modification effectiveness and to forecast effect on short-term, streamflow responses for water right administration. Use of wind tunnel modeling to study nuclei diffusion in mountainous areas with verification from field experiment date and to predict diffusion for design of experiment and other projects. Use of a cooperative computer laboratory to integrate developed mathematical models and fully analyze results of seeding projects and cooperative experiments. Development of basic concepts and optimum statistical designs for scientific precipitation modification experiments and improved statistical evaluation procedures. Studies on the physics and dynamics involved in modifying warm clouds for enhancing precipitation and design of practical modification techniques. Development of remote sensors, including radar, that will measure those meteorological parameters important to effective cloud seeding and real-time analysis systems and recognition displays for operational control during experiments and eventual routine operations. Analysis and forecasts of stormtype characteristics and associated meteorological studies including region-wide climatological surveys of natural nuclei availability. These investigations will be made in conjunction with the benchmark programs and planning for the West Wide water studies.

Funds (in millions of dollars) expended by DOI for weather modification during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
4.70	4.80	6.50

Department of Transportation

Fog dispersal.—In cooperation with other Government agencies and industry, DOT's Federal Aeronautics Administration (FAA) will conduct R. & D. to achieve operational weather modifications, such as fog dispersal in terminal areas.

Atmospheric pollution may influence the weather and attempts to modify it may create pollution. Knowledge of the interaction of pollution and efforts at weather modification is essential.

Specialized instrumentation to measure cloud physics variables is being developed. Cloud models for modification experiments are being developed. Efforts to find more effective weather modification materials are continuing. Major emphasis is on systems which will disperse warm fog and frontal cloud formations.

The results of studies of marine aerosols, droplet growth processes, and nuclei climatology will be applied through experiments with both actual and model weather systems. Promising results will dictate process and equipment development.

Funds (in millions of dollars) expended by DOT for weather modification during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
3.00	2.30	3.50

National Aeronautics and Space Administration

NASA's field tests of warm fog seeding experiments were continued by using sodium chloride and urea. This confirmed previous results that clearing of dense fog could be attained. The fog-bound airport at Elmire, N.Y., was used as the target area. Effort will be devoted to investigating the life cycle of warm fog to determine the principal parameters (radiation, turbulence, and hydroscopic nuclei) affecting its generation and persistence.

Funds (in millions of dollars) expended by NASA for weather modification during fiscal years 1969–71

are as follows:

1969	*1970*	*1971*
0.18	0.20	0.14

National Science Foundation

Weather modification studies include modification of ice nucleation mechanisms, droplet coagulation and coalescence, cloud electricity, and hygroscopic nuclei, storms. Social, economic, legal, and ecological aspects of weather modification are also considered.

The national hail research experiment in Colorado under the National Center for Atmospheric Research (NCAR) is designed to determine how hail forming mechanisms of severe storms may be modified to reduce hail damage on the ground.

A cloud seeding pilot project in the Upper Colorado River area has successfully demonstrated the potential of weather modification using groundbased seeding with silver iodide.

Research in atmospheric electricity will continue to establish the role played by electrical fields and electrostatic forces in promoting coagulation of cloud particles and rain production. Studies of the electrical structure of discrete convective clouds will be continued to determine the location, polarization, and extent of the charge centers. Artificial ion injection will be used as a tool of research to explore charging mechanisms and possible precipitation enhancement.

Funds (in millions of dollars) expended by NSF for weather modification during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
2.70	3.60	4.50

Protecting and Enhancing the Environment

Funding of R. & D. pertaining to protecting and enhancing the environment for fiscal years 1969, 1970, and 1971 is reported in table 7 (p. 48).

ANALYSIS OF ENVIRONMENTAL SYSTEMS

In addition to research on the interactions of man's various developmental and technological activities on separate components of the environment, and on the structure and functioning of individual terrestrial and aquatic ecosystems, there is a need for more comprehensive study of total environmental systems.

National Science Foundation

NSF currently sponsors research designed to develop a holistic approach to regional planning that will identify and characterize probable major environmental problems and find ways of preventing their occurrence. Related research seeks to relate the flow of goods and services to the occurrence of environmental problems. Other research is examining new approaches to land use allocation which will accurately predict the environmental consequences of different mixtures of land use. An assessment of the national energy problem is coupled with research to identify and exploit new technological alternatives for energy generation, storage and transmission, particularly in ways that will minimize environmental impacts.

Funds (in millions of dollars) expended by NSF for analysis of environmental systems during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0	3.07	0.11

FISHERIES AND WILDLIFE RESOURCES

The Nation's forest, range, and agricultural lands furnish shelter and food for more than 10 million head of big game and for countless numbers of small game and nongame animals and birds. Our native wildlife also represents an increasingly valued part of the environment for the interest, variety, and beauty it adds to the landscape. Similarly, freshwater streams and lakes are host to some 25 million fishermen annually, and the 52,000 miles of tidal shoreline give access to offshore and deepwater sports fishing for additional millions. Although this resource is potentially self-perpetuating, protection and management practices must be improved, intensified, and more generally applied to offset increasingly heavy depletions. These occur not only from natural causes such as predators, disease, and weather—and from the annual harvest by hunters and fishermen, but also, and of mounting importance, as a result of damage to aquatic and terrestrial habitats by man's activities.

Department of Agriculture

Current research by the Department seeks to characterize the principal interactions between wildlife and their environment and to determine food and cover requirements of game animals. Investments are especially high in deer and elk habitat research. Work is concentrated in the deciduous forest ecosystems in the East, and in the mountain forest and rangeland ecosystems in the West. Methods of manipulating forest and range vegetation to optimize food and cover conditions are being developed. Studies of alternative levels and combinations of multiple use management emphasize the integration of wildlife with timber and livestock production. A small start recently has been made

in determining effects of certain forest practices on aquatic habitat of anadromous fish. Habitat requirements of a few selected endangered species of birds and animals are also being investigated.

Research in the next 5 years will place more emphasis on desert, grassland, coniferous forest, and wetland ecosystems. To insure rapid progress toward enhancing wildlife values, more attention will be given to establishing a sound basis for forest and range management systems that will augment wildlife values without sacrificing water, timber, forage and other benefits. Added emphasis will also be given to methods of preserving and enhancing aquatic habitat in rivers and lakes in forested areas; to the food and cover requirements of nongame birds and animals, particularly endangered species; to improving strains of wildlife food plants; and to the study of insect and disease pests of important wildlife food plants.

Funds (in millions of dollars) expended by USDA for fisheries and wildlife resources during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
1.95	2.22	2.33

Department of Commerce

The DOC research objectives are to develop knowledge of the biological characteristics and requirements of living marine resources and an understanding of their relationships to, and the consequences of, changes in their physical environment. Fishery models are designed to predict changes in abundance and location of fishery stocks and to predict the effects on fishery stocks of manmade or natural changes in marine, estuarine, and anadromous habitats. Basic studies of marine fish and shellfish will identify races or stocks and their geographic distribution; describe their life cycles, migrations, and seasonal changes in abundance; and determine the causes of variations in abundance and distribution. DOC also conducts investigations leading to improved understanding of jellyfish populations to develop possible methods of controlling or eradicating this marine pest.

Future work will involve biological and ecological studies of the basic requirements of the living marine resources and the physiological implications of pollutants introduced by man. Another field of research will emphasize the natural and modified processes that operate in marine ecosystems and the practical methods of managing the ecosystems to restore, maintain, or enhance the production of species useful to man. Emphasis will be placed on an understanding of the coastal and oceanic processes and the role of the living marine resources within the marine ecosystem. Systematic sampling of waters and biota will be carried out in selected estuarine, coastal, and high seas environments to obtain relevant physical, chemical, and biological data to permit detection, analysis, and prediction of environmental change and its consequences.

Funds (in millions of dollars) expended by DOC for fish and wildlife resources during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
14.22	15.16	13.15

Department of the Interior

The DOI's R. & D. activities include fish and wildlife biological research, and Federal aid to States for research on local fish (about 30 percent) and wildlife (about 70 percent) problems. Department scientists are measuring and analyzing the effects on fish populations of various ecological imbalances, such as water temperature increases resulting from the addition of heated waste water to streams and lakes and the immediate and chronic toxicity, persistence, and detoxification of pesticides and their residues. They are also investigating the cycling of heavy metals through aquatic ecosystems. Research is conducted on the prevention, detection, and control of fish diseases to limit the contamination of public waters through introduction of carriers. Fish hatchery management and rearing methods are being improved. A strong research program is maintained to develop more complete knowledge of the environmental requirements of waterfowl and other migratory birds throughout their ranges. Also included are studies of food, shelter, and mating requirements of certain endangered bird and animal species. The overall effects of a broad spectrum of environmental pollutants on the reproduction and survival of wildlife are receiving increased emphasis.

DOI plans for the immediate future envisage no significant changes from the present program.

Funds (in millions of dollars) expended by DOI for fisheries and wildlife resources during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
17.30	17.20	19.10

The USDA and the DOI under a memorandum of understanding approved in October 1960, collaborate closely in the planning and conduct of their

respective programs. USDA has primary responsibility for research on the habitat and develops needed knowledge on how favorable food and shelter conditions may be maintained and enhanced. USDA also does research on the impacts of forest and range land management practices on fish and wildlife habitat. DOI has responsibility for studying the biology and life processes of fish and wildlife, their habitat requirements, and their parasites, diseases, and predators.

RECREATION RESOURCES

Concentrations of population, combined with more leisure time, greater mobility, and higher net income, have greatly intensified the demand for outdoor recreation. Existing facilities and resources are often overtaxed, and development plans fail to keep up with changing public needs and preferences and with advancing technology. Increasingly, these deficiencies are leading to environmental deterioration and to an unsatisfactory or unfulfilled recreation experience by millions of people. Resource planners and managers must have better information on which to base their decisions if the Nation's requirements for a healthful, diversified, and rewarding array of recreation opportunities are to be met.

Department of Agriculture

USDA is developing more accurate techniques for measuring recreation use, for evaluating trends in types of recreation activity and for projecting future needs. Criteria for identifying, measuring, and appraising the total recreation potential of forest and other wild lands are being established. An important objective associated with the Department's responsibilities for rural area development is to learn how to increase the profitability of rural recreation enterprises. Research is also concerned with finding out how recreation opportunities can be provided to enhance the quality of life for low income and underprivileged segments of the population, both in rural and urban situations. Methods of integrating recreation activities with other land and water uses are being tested. The Department also conducts multidisciplinary research to evaluate the nature, duration, and severity of impacts of high-density recreation use on ecosystem components.

Future research is expected to develop more accurate yardsticks for determining recreational needs of major population segments and methods of applying these findings in rural planning for expanded recreation areas and facilities. Recreation users of all types will be studied to determine their interests, motivations, and reactions to outdoor experiences in order to improve the planning, development, and management of recreation resources and facilities. Greater emphasis will be placed on understanding, preventing, and correcting adverse environmental effects resulting directly or indirectly from recreation activities. Additional research is planned on a number of problems which have so far received little attention, such as criteria and guidelines for policies with regard to use of snowmobiles and other off-highway vehicles in parks, recreational areas, and other public wild lands.

Funds (in millions of dollars) expended by USDA for recreation during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
1.46	1.55	1.60

Department of the Interior

The DOI in addition to coordinating a variety of interrelated research activities, supports several research projects that relate to the protection and enhancement of recreation resources. Projects supported during the past 3 years include: (1) Examination of the optimum use of natural areas to determine patterns of preservation and development of natural areas that will maximize net benefits to society, (2) study which will focus on the substantive policy and political practices of wilderness and wildlife preservation at the national level of government, (3) review of the structure and adequacy of governmental decision making in the broad areas of environmental policy and land use planning, and (4) study of wild and scenic rivers to determine which rivers or stretches of rivers should be preserved in their free-flowing condition for the benefit of present and future generations. Future research will be expanded on these and related problems.

In the next 5 years the Department will endeavor to expand its existing programs while giving added encouragement to privately supported investigations and doctoral dissertation projects in the area of identified need. More attention will be given to the field of motivational research and to determining the kinds of recreational opportunities which are or which are likely to be most desired and sought after. Research to assist in the development of improved methods for determining demand for and use of

projected recreation developments is also planned. Similarly, methods for equating qualitative values with quantitative values will be investigated.

Funds (in millions of dollars) expended by DOI for recreation and resources during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0.10	0.10	0.10

RURAL AND WILD LAND ENVIRONMENT

This category of environmental research and development activities includes two major problem areas: (1) Improving the quality of living for rural residents, and (2) protection and enhancement of the esthetic and amenity values of the outdoor landscape for all Americans. It does not include related problems of pollution abatement, recreation resource management, and basic ecological knowledge and understanding, all of which are covered elsewhere in this report. Rather, it relates primarily to the development and application of sound concepts and practices for managing vegetation to achieve socially desirable objectives. These objectives include minimizing adverse impacts of natural and manmade forces and creating for man's enjoyment a more complete and esthetically pleasing rural environment.

Department of Agriculture

Research is conducted on a variety of culture and use problems which involve trees and other plants produced or established for functional or esthetic purposes. Little is known, for example, about how to establish and maintain flowering ornamentals like dogwood or redbud, "screenings" of spruce or pine, or seed-bearing plants and shrubs for wildlife, in a broad range of wild land settings. Significant cultural problems are associated with the establishment of trees needed for landscape purposes at such adverse sites as cuts and fills and in soil-compacted forest recreation areas. Studies in landscape design and management also extend to the use of tree and shrub plantings to lessen other land use eyesores resulting from past mistakes and for making high-speed highways safer and more attractive for travelers. Fundamental ecological knowledge is used to devise forest management systems which will permit extraction and utilization of timber without unacceptable or lasting impairment of esthetic values.

Research is also conducted on the rehabilitation of stripmined areas. Current hydrologic, engineering, and ecological studies emphasize the characterization, stabilization, and revegetation of mined-out areas on steep slopes and acid soils. Better practices are being developed for establishment, protection, and culture of windbreaks and shelterbelts in the Great Plains to ameliorate the harsh environment around farm and ranch homes and to protect crops and livestock. Forests and other rural landscapes must be protected from the depredations of insects and diseases and from destruction by fire. Department scientists seek safer, less expensive, and more effective ways of doing this.

In the future, more emphasis will be placed on research in rural land use planning, including the development of a better basis for determining uses of forest and range land that will insure the greatest long- and short-term social and economic benefits. Increased emphasis will also be given to techniques for forest landscape management and the development of alternative timber harvesting systems which will meet esthetic requirements. Plans call for an expansion of research to establish a sound and rational basis for evaluating esthetic and other environmental values of forests and other wild land. A major research objective will be to find ways of minimizing pest-induced deterioration of forest landscapes by means of genetic and cultural pest resistance and through biological control of pests wherever possible.

Funds (in millions of dollars) expended by USDA for rural and suburban environment during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
6.50	6.78	7.63

Department of the Interior

The DOI is investigating ways of improving environmental and economic conditions in areas damaged by past mining activities. Physical and chemical treatments of mine waste embankments are applied experimentally to modify acidity or alkalinity, improve structure and moisture-holding capacity, and reduce erosive tendencies. Recent tests with fly ash, for example, indicate that a large tonnage of this powerplant waste might be used to restore barren areas to attractive and productive use. Effective means of revegetating and stabilizing spent oil shale dumps, mined-out phosphate deposits, and other similar consequences of mining are being developed.

Inasmuch as much of the extraction technology now applied is predicated on the use of land as a sink for mineral wastes, improved extractive systems utilizing technological advances in the mining process are being designed and tested. Research is also conducted on methods of filling underground voids to prevent extensive land subsidence and for more effective and less costly control of mine fires.

No substantial shifts in direction or emphasis of the Department's R. & D. activities are planned for the immediate future.

Funds (in millions of dollars) expended by DOI for rural and wild land environment during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0.83	0.91	0.97

URBAN AND SUBURBAN ENVIRONMENT

Urbanization and related consequences of rapid population growth and economic expansion have greatly diminished the attractiveness and livability of the environment in and around population centers. Open space and scattered woodland oases with their little enclaves of bird and animal life have been disappearing. Parks are deteriorating from neglect and overuse. Trees, grass, and flowering plants suffer from the varied impacts of hostile surroundings. The grace, order, and charm that could and should be characteristic of well-planned municipalities seem almost forgotten. All this is true not only of the great metropolitan centers but also of the thousands of other cities, towns, and suburbs where 70 percent of our people dwell.

Recent years have seen a public awakening to the seriousness of urban blight and suburban sprawl and a gradual realization that they can no longer be ignored or allowed to continue unchecked. Concern for the poor and underprivileged millions crammed into slum areas now embraces not only the day-to-day struggle to stay alive but also the need for improving the quality of their living. Demands are intensifying for better understanding of just what the problems are and how they may be corrected. The goals for research and development are in part to find ways of restoring already damaged environment under conditions of continuing use and abuse, and in part to learn how to prevent deterioration in urban renewal programs, or in new or developing communities, through more intelligent and forward looking planning.

Department of Agriculture

The programs of USDA deal with protection, establishment, and culture of trees, turf, and ornamental plants. They concern both problems of naturally occurring vegetation in city forests, parks and open-space areas, and of special purpose plantings in public gardens, along streets, and around buildings. Particular attention is given to stress tolerance, pest resistance, and improvement of functional characteristics. Experimentation with the genetics, breeding, and selection of new species and varieties is emphasized. Safe and effective control measures are being sought for such critical pest problems as Dutch elm disease and the gypsy moth. Prevention and control of forest and brush fires in intermingled residential and wooded areas especially in critical situations, such as those existing in the Los Angeles area, are being intensively investigated. Research begun in 1971 will deal with optimum uses, the dynamics of change, and management alternatives of wooded areas in the densely populated Northeast.

Over the next few years USDA expects to devote more attention to identifying, characterizing, and evaluating urban and suburban environmental problems. A broadened and more comprehensive attack is planned on selected, high priority needs which promise prompt and effective research payoff. Improved plant materials for city parks, streets, and homes will undoubtedly rank high. More useful and dependable decision making and planning models will be sought, involving social, economic, biological, and ecological analysis of forest and related resources in areas of constantly increasing human pressures. New approaches to improved management and use of forested municipal watersheds will be investigated.

Funds (in millions of dollars) expended by USDA for urban and suburban environment are as follows:

1969	*1970*	*1971*
4.61	4.95	5.63

Department of Transportation

Research in DOT is designed to develop, test and demonstrate methods by which transportation systems serving the Nation's population centers cannot only avoid adverse environmental impacts but actually contribute to community social and environmental goals and help make metropolitan areas more attractive. R. & D. activities will establish criteria and techniques for identifying and evaluating environmental and aesthetic impacts of specific components of transportation systems. The location,

structure, and functions of alternative transportation modes in terms of their relative environmental effects will be studied. Available information on contributions of surface vehicles and aircraft to air, water, land, and noise pollution will be synthesized into guidelines for selecting highway routes and airport locations which will minimize environmental impairment. The results of the Department's research will be made available for use by metropolitan decisionmakers in developing overall policies and plans.

The above research will continue for the next several years.

Funds (in millions of dollars) expended by DOT for urban and suburban environment during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0	0.65	0.75

Department of Housing and Urban Development

The objectives of the environmental quality research and demonstration programs in HUD are to provide the knowledge base and environmental planning and management techniques needed by the urban planner and decisionmaker and to seek out ways to bring the nation's science and engineering capability to help solve pressing urban and environmental problems. These programs consider the relationships between community development and redevelopment and environmental quality and encourage management of the physical environment to be more responsive to the needs of the urban dweller. Studies include the feasibility of small-scale combined processing plants to treat solid and liquid wastes, generate electrical power and use the leftover heat in the surrounding neighborhood for home heating, air conditioning, and hot water. Also included is work on noise abatement, geologic hazards, application of advanced communications for more effective urban operations, utility installation techniques such as tunneling and trenching and the location and distribution of public utilities. Work is also underway to examine candidate technology and approaches that may be used at the urban renewal and new communities scale.

Future plans are to design experimental demonstrations for the waste management systems that are ready for application. Also research will continue on the urban environmental planning process with a focus upon earth hazards and natural resources. An emerging effort is in the area of earthquake hazard reduction through improved seismic risk zoning, land use, building and construction practice.

Other objectives of research and demonstration programs are to help establish, preserve, improve, and beautify open space land which is essential to well-balanced, long-range urban and suburban development. The programs seek to define more reliable criteria for, and design new and improved approaches to, the selection and allocation of land for parks, greenbelts, wooded buffer strips, and recreation areas. Studies relate to characterizing the quality of open space in terms of its specific purposes and to determine optimum distribution, location, size, and character of open space areas. The influence of topography, traffic and business patterns, zoning regulations, needs of the people, and related factors are evaluated. Other studies are leading to improved design and planning of parks for more efficient maintenance, maximum public enjoyment, and greatest safety and security.

This research will be continued in the next few years.

Funds (in millions of dollars) expended by HUD for urban and suburban environment during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
0.77	2.09	3.68

WATER RESOURCES

The most critical problems affecting our Nation's water resources are those involving pollution, floods, and adequacy of supply. Water pollution is dealt with as a separate topic elsewhere in this report. Floods impact primarily upon human health and welfare and on property values and are outside the scope of this report. Certain R. & D. activities oriented primarily toward improving the amount, timing, and availability of water in streams and in natural and manmade impoundments are discussed here as relevant to environmental quality.

Precipitation in the 48 contiguous States, amounting to about 2½ feet for every acre of land each year, represents the source of the Nation's fresh water supply. Seventy percent of this annual increment is returned to the atmosphere through evaporation and transpiration. The remaining 30 percent finds its way into streams or ground water and is potentially available for use. Man's ability to degrade and destroy this water resource has been conclusively demonstrated. What has not been fully proved or demon-

strated is the potential for reducing the 70 percent lost to evapotranspiration, or for making more efficient use of the 30 percent that stays on or within the earth's surface. The headwaters of all major rivers in the United States and more than half the streamflow originate in forests, associated rangelands, or alpine regions characterized by relatively high annual precipitation. The management of these headwaters, including the vegetative mantle, has a great deal to do with the fate of this precipitation and with the timing and amount of water yield. Similarly, research has shown that the use and management of agricultural lands has a profound influence on the hydrologic characteristics of soils and, hence, on the infiltration and movement of water. However, the technology for producing predictable effects where, when, and as needed has not been devised. It is still not possible to prescribe vegetation or land treatments which will cause specified changes in streamflow and ground-water recharge in watersheds with heterogenous soil, geologic, topographic, and precipitation patterns.

Department of Agriculture

USDA develops knowledge that will lead to better methods for predicting effects of alternative systems of land treatment, water harvest, and water protection measures on streamflow and ground water supplies. Research includes experimental manipulation of vegetation to increase throughfall, reduce transpiration losses—particularly from riparian vegetation in regions of low rainfall and the treatment of agricultural and forest soils to promote water infiltration and increase storage capacity. Research is also conducted on the manipulation of forest cover and on the dynamics of air movement as they affect snow accumulation and rate of melt in high mountain areas. Mathematical models are composed for quantitatively describing the hydrologic performance of watersheds under varying types and levels of land use and management. Some of the most successful vegetation management methods involve the use of herbicides and prescribed fire, both of which can create environmental problems. Other types of treatment result in badly scarred landscapes. Alternative approaches must be found which will avoid air or water pollution or an aesthetically unattractive effect.

No significant increases in research on water supplies are planned, and there may actually be some reduction in effort in order to give greater impetus to water quality research. Also, there will be more emphasis on making better use of information already available, especially through the development of modeling systems. Much of the knowledge on effects of removal of riparian vegetation, forest cover manipulation, and agricultural soil amendments is not being fully applied because it has not been integrated with other, closely related data, and incorporated into total soil and water management prescriptions.

Funds (in millions of dollars) expended by USDA for water resources during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
5.75	6.12	6.15

Department of the Interior

Several DOI Bureaus are involved in a broad-based program, the purpose of which is to help assure a continuing supply of water sufficient to meet the Nation's requirements. One phase of this program involves study of the effects of man's activities on the availability, movement, and efficiency of use of water resources. Impacts of urbanization, highway systems, and irrigation projects on water yields and flow rates are evaluated. Institutional structures which influence water policies and programs and the nature and mechanisms of constraints which they impose at all levels of government are investigated. Opportunities for making wider use of water heated during industrial processes or otherwise degraded in quality are being sought. Adverse impacts of major water development and management operations on the overall environment and ecology of an area are being evaluated to provide information which can be used to structure projects for minimizing deleterious effects and maximizing enhancement effects. Techniques are being developed to prevent or ameliorate side effects of saline water conversion which may arise from improper disposal of the brine effluent produced. Research on upgrading or renovating waters which have become salty by multiple usage will, in essence, provide "new water," a particularly important source of water resource enhancement in areas of low precipitation.

The DOI's existing research programs are indicative of future needs and reflect the probable directions of research over the next few years.

Funds (in millions of dollars) expended by DOI for water resources during fiscal years 1969–71 are as follows:

1969	*1970*	*1971*
2.63	2.72	3.88

Alternatives to the Use of Pesticides

INTRODUCTION

Pesticides have contributed greatly to the increased production of food and fiber by controlling the pests that compete with crops, and the human health by controlling the vectors of various diseases. Despite these positive attributes, the use of pesticides has also been beset with some problems. Long persistance in the environment and bioconcentration through a food chain, twin attributes of some chlorinated hydrocarbons, have the potential for causing adverse effects in nontarget species, especially those at the top of food chains. More than 200 insect species have developed resistance to one or more insecticides. Beneficial insects are often affected as much by an insecticide as are the pest species. Fish and other aquatic organisms may suffer from the toxic effects of pesticides applied on land for the control of one or several pests.

Because of the adverse effects of pesticides, research has been underway many years to find effective and safe alternatives to the use of pesticides.

Funding for R. & D. pertaining to alternatives to the use of pesticides for fiscal years 1969, 1970, and 1971 is reported in table 8 (p. 53).

Department of Agriculture

In the field of forestry, losses are experienced each year because of attack from insects and disease, and because of competition from undesirable vegetation. Natural disease epizootics regulate populations of some insect pests, but significant losses result from others.

Biological and cultural control methods are being developed for controlling such insects as the douglas-fir tussock moth, European pine sawfly, larch casebearer, gypsy moth, saratoga spittlebug, European pine shoot moth, and the spruce budworm. Parasites and predators have been successfully established for the control of such insects as the European elm bark beetle, balsam wooly aphid, and larch casebearer. Although most of the parasites and predators have been extended into operational size units. Attractants for gypsy moth and bark beetles are available and have been field tested. Their use facilitates trapping to determine the severity of infestation and they may ultimately be of use in actual control operations.

For the control of forest diseases, breeding programs are actively underway to develop resistant varieties. Silvicultural manipulations, taking into consideration soil and climatic requirements and species mixtures, are used to improve tree growth and health so that the use of synthetic pesticides are not needed, or needed only infrequently, to maintain forest and environmental quality.

Breeding programs are also underway to develop timber species whose faster initial growth, combined with intensive cultural methods, greatly reduces the need for chemical control of competing vegetation.

Breeding programs on agricultural crops for resistance to insect and disease attack have been a first line of defense for many years. Most of the successes have been in the field of disease resistance, but varieties that are resistant to specific insects have also been developed. Resistant varieties of wheat are virtually immune to the Hessian fly, strains of alfalfa have been developed that are resistant to the spotted alfalfa aphid, and good progress has been made in developing sweet corn varieties resistant to the corn earworm.

Biological control, using nonnative parasites and predators plays a vital role in keeping pest populations under control. More than 650 species of parasites and predators have been introduced from foreign areas. Of these, about 150 have become established. Among notable successes are the control of St. Johnswort by a *Chrysolina* beetle and control of cottony-cushion scale by Vedalia lady beetles.

Microbial agents can be equally as effective as

parasites and predators. Milky spore disease for the control of Japanese beetle has been used for many years. More recently, *Bacillus thuringiensis* has been used for the control of such insects as the imported cabbage worm, tobacco budgworm, and the alfalfa caterpillar. Additional developmental work is now being conducted to prove the efficacy and safety of a polyhedral virus for the control of various insects.

In the field of aquatic weed control, the *Marisa* snail and a fish, the white Amur, have promising potential.

Advantages of the male-sterile technique were proven with the screw-worm, a major pest of livestock. Sufficient information has been developed to indicate that the technique may prove useful in controlling Mediterranean fruit fly, oriental fruit fly, Mexican fruit fly, pink bollworm, boll weevil, tobacco hornworm, codling moth, and fruit flies of the genus Drosophila.

Considerable research is being conducted on the isolation, identification, and synthesis of attractants. These may be used in the future directly in control activities or in combination with traps. Research is also underway to determine specific portions of the light spectrum which may attract insects to a greater degree than to other portions of the spectrum.

Integrated control offers important potential for the future. Its use depends on a combination of many control methods rather than to rely on any one. Successful application requires a detailed knowledge of the relative effectiveness of a large number of combinations of control strategies, a detailed understanding of the ways in which they interfere with and complement each other, and an ability to select appropriate methods in diverse circumstances. Success probably will depend on a detailed knowledge of the biology of the crop and pest, and on the construction of mathematical systems models.

Funds (in millions of dollars) expended for alternatives to the use of pesticides are as follows:

1969	*1970*	*1971*
32.05	33.64	37.74

Corps of Engineers

The research program is directed toward the control of aquatic vegetation by nonchemical methods, particularly biological control. Research underway includes an evaluation of a flea beetle for the control of alligator weed, the *Marisa* snail for the control of many species of aquatic vegetation, and the white *Amur* for general aquatic vegetation control.

Funds (in millions of dollars) expended for alternatives to the use of pesticides are as follows:

1969	*1970*	*1971*
0.20	0.30	0.30

National Science Foundation

Research supported by NSF falls principally into two areas (1) insect behavior, physiology, and biochemistry, and (2) the ecological dynamics of natural and modified systems. Both areas are essential for the development of more sophisticated pest control strategies, particularly in terms of integrated control. Field studies and laboratory simulations are included in the total program.

Funds (in millions of dollars) expended for alternatives to the use of pesticides are as follows:

1969	*1970*	*1971*
0.83	0.80	0.90

Noise

Noise, for the purpose of this study, addressed both natural and manmade sound patterns which generate, propagate, attenuate, or otherwise affect the natural or human environment. Although several Federal agencies are involved in R. & D. concerned with noise as a pollutant, the majority of the funding effort is centered in DOD, DOT, HUD, and NASA. These programs are almost exclusively directed toward aircraft noise—its reduction at the source, attenuation once generated, and human response thereto. The R. & D. is both basic and applied. Approximately 20 to 25 million dollars per year are directed toward noise R. & D. with the NASA expending about 70 percent of the funding effort. Funds expended in fiscal years 1969, 1970, and 1971 for R. & D. pertaining to noise are reported in table 9 (p. 55).

AIR

Several Federal agencies are involved in R. & D. concerned with noise as an air pollutant. The majority of the funding effort is centered in DOD, DOT, NASA, and NSF. Research emphasis has been placed on aircraft propulsion system noise and its suppression. Other efforts involve research on noise propagation and sonic boom. The R. & D. is both basic and applied. For the purpose of illustrating the noise programs and progress, major efforts in R. & D. have been placed in two categories: Aircraft propulsion system noise and other aircraft noise research.

Aircraft Propulsion System Noise

Quiet engine.—Demonstration of the technology and design innovations necessary to reduce the production and radiation of noise in turbofan engines. This experimental turbofan engine will have a takeoff thrust rating of 22,000 pounds. The engine will utilize existing core designs but will incorporate fan characteristics and noise suppression techniques which promise to reduce noise substantially. Test hardware includes full-scale and acoustic-scale model fans.

Fan tests.—Test operations have begun in the modified fullscale test facility. Initial fan tests will include: (1) A 1.5-pressure ratio fan with and without an acoustically treated nacelle (acoustic treatment will be varied by taping over porous surfaces to provide information on suppressor effectiveness); (2) a 1.4-pressure ratio fan; (3) the 1.5-pressure ratio fan with reduced stator blade number; (4) the 1.5-pressure ratio fan without stators; and (5) the 1.5-pressure ratio fan with various motor-stator spacing arrangements.

Fan results obtained to date translate into four-engine aircraft flyover noise levels of 104 effective perceived noise decibels (EPNdb) at the 3.5 nautical mile point on takeoff power, and 102 EPNdb at the 1 nautical mile point on approach (which are essentially the Federal Air Regulations—Part 36 (FAR 36) noise limits). With an acoustically treated nacelle, the values should be reduced substantially below the FAR 36 criteria.

Nozzle configuration.—Sea level static noise measurements are being continued on nozzle concepts suitable for supersonic cruise aircraft. Nozzle concepts investigated in conjunction with a J85 afterburning turbojet engine include a reference convergent primary nozzle, a variable flap ejector, an auxiliary inlet ejector, and a plug nozzle. Results indicate that the plug nozzle has an inherent capability for reduced noise levels. Measurements of the noise associated with these engine-nozzle-nacelle configurations have been extended to fly by tests when installed on an F–106 aircraft.

A large rocket engine is being utilized to generate high temperature, supersonic jets with physical and thermochemical properties similar to those of a large afterburning turbojet. This system will be used to study the contribution of the mixing region on the perceived noise level independent of the contributions of any upstream turbomachinery. The investigation

will attempt to determine: (1) The influence of velocity distribution at the exist of the nozzle, and (2) the influence of turbulence, particularly in the boundary layer, on the noise radiated from supersonic jets discharging into the atmosphere at stagnation temperatures (about 3,000°F.).

Supersonic jet noise generation.—A theoretical and experimental study to provide a better understanding of jet noise generation and suppression in supersonic jets and to develop an efficient supersonic jet noise suppressor continues. Tests to date indicate that weak shock waves from six small rods placed at the periphery of a mach 1.4 jet decreased the overall sound power level by 6 db. While use of a shroud in conjunction with the six rods reduced the sound-power level by 18 db, multiple tubes were responsible for a 12 to 15 db reduction over that of a single nozzle configuration. Analytical procedures have been used to determine the flow conditions needed to achieve up to 20 db noise suppression from supersonic jets. Also determined were the large shielding effects of multitude supersonic jet configurations, and a theory was developed for the prediction of multiple tube suppressor characteristics.

Lift fan noise.—The lift fan program uses a 36-inch diameter fan having a pressure ratio of 1.3 to explore the effect of vane number (45 and 90), rotor-stator spacing (1.5 to 2.0 chords), and blade lean. The best configurations will be investigated with acoustic treatment applied in the fan flow path and on the exit louvers. Later tests will also be made using a blade with a serrated leading edge. Noise measurements will continue to be taken during tests of aircraft in the 40- by 80-foot wind tunnel. This will establish the relative noise levels of complete VSTOL aircraft configurations throughout the transition flight regime and at cruise condition. The serrated leading edge concept continues to receive attention. Results to date at a speed of 377 feet per second indicate that the most effective configuration consists of small triangular teeth mounted on an extension of the wing chord. However, it appears, from tests conducted with a serrated leading edge on a 6-foot diameter tail rotor operating at 750 feet per second, that a noise reduction potential may no longer exit at the higher speeds.

Jet noise.—Jet exhaust noise research involves both nozzle configuration and flow consideration. The basic acoustic characteristics of slot nozzles of the type used in augmented flap systems, and peripheral nozzles of the type used in ground effects machines are under study in-house and at the University of Tennessee. In-house studies also provide for altering the sound speed profile of a jet exhaust and for adding flow shielding to radically change its noise radiation pattern. The addition of various substances (solid particles, aerosol, secondary air flows, ionized particles) to the jet flow to alter its noise generation and radiation characteristics is under study.

Rotating blade noise.—The generation and prediction of rotating blade noise is important for various propulsion units, such as propellers, helicopter rotors, fans, compressors, and turbines. Studies that relate particularly to propellers include the acoustic evaluation of resonators for ducted propellers and a theory for predicting the oscillating pressure loads on propeller ducts and the far field radiation and the effects of inflow angle on the noise generation of unducted propellers.

The flight evaluation of helicopter noise reduction schemes has been completed. These were to evaluate various design modifications and specifically the rotor systems. Flight tests have also been made to evaluate the significance of unloading the rotor during flight by deployment of an auxiliary wing surface.

Tests are proceeding with a multistage laboratory compressor to study the noise loads on the compressor case near the rotors, and the propagation of noise through the blade rows.

Noise generation from large fan engines.—Another project being conducted is concerned with multiple pure tones and optimum lining generated by blade rows of an axial flow fan, and the determination of the effect of asymmetries in the inlet flow on the propagation characteristics in the fan duct. Recent studies have indicated that variations in blade spacing are not the source of significant multiple pure tones. Present studies are being continued to determine blade stagger angle tolerance and blade shape as possible causes of wave coalescences.

Broadband noise mechanisms.—This analytical evaluation is concerned with the simultaneous interaction of shock waves in a turbulent region, and the interaction of blade wake turbulence with a heavily loaded downstream blade. This latter mechanism will be studied experimentally on an airfoil at high angles of attack with incident fluctuating flows.

Fluid mechanics of edgetones.—This research program investigates the mechanism of aerodynamic sound production by free shear layers, such as separated boundary layers and impinging wakes on rigid surfaces. Generation of edgetones associated with a turbulent jet both with and without a wedge in the stream has been explored, and a general theory is being formulated.

Turbulent jet noise generation.—Research is oriented toward the noise generation and propagation by turbulent fluctuation in a turbulent jet, and the study of possible methods for alleviating this noise generation. Flow measurements have been obtained in a subsonic stream downstream of a screen and will be extended to include a supersonic jet. Spectral analysis of the measured hot wire data will be conducted in a computer program.

VSTOL noise characteristics.—Problems associated with VSTOL noise characteristics are under study. This effort is an extension to an existing study relating to the subjective evaluation of noise from general aviation aircraft. The noise characteristics of some of these aircraft contain factors common to VSTOL aircraft. We have been concerned for some time that noise characteristics peculiar to VSTOL vehicles, such as rotor blade slap, temporal noise patterns, complex modulation, and tone effects may contribute to the difficulty of calculating perceived noise levels. The extension of noise certification regulations to VSTOL aircraft and the need to stimulate noise reduction effort in VSTOL systems design support this requirement.

Reconnaissance/surveillance aircraft noise.—Objectives of this noise research are to decrease aural detection for reconnaissance/surveillance aircraft; to alleviate the problem of acoustically induced structural fatigue; to reduce the overall noise environment for flight crew, ground crew, and neighboring communities; and to study radiated noise from aerodynamic bodies in flight and methods of reduction. Tests have been conducted of a low-noise propeller, a test rig has been developed and recommendations for the design of minimum vortex noise propellers have been made. A one-time 3 million dollar effort to flight test a quiet aircraft for reconnaissance/surveillance has been successfully completed.

Propeller noise.—Further work on radiated noise from aerodynamic bodies in flight and reduction of propeller noise continues. Jet propulsion systems for reconnaissance/surveillance aircraft are being studied. The objective is to achieve aural nondetectability at relatively low altitudes. Acoustic evaluation of propeller designs will continue in-house as will development of a small turbine engine of minimum noise.

Helicopter noise.—Studies are being made to reduce the noise levels of both helicopters and fixed-wing aircraft to reduce the probability of enemy detection. These efforts also contribute indirectly to abatement of noise pollution. Blade tip speed, blade geometry, number of blades and blade materials are being studied with a view to reducing helicopter noise. Techniques for measurement of noise levels have been improved. The effects of varying frequencies upon the ability of humans to detect aircraft noise have been determined. Short-range plans are to continue the search for means to reduce aircraft noise.

J–65 inlet suppressor.—A series of systematic variations in inlet suppressor geometry were tested on a J–65 engine. The test series is complete.

Suppression concepts study.—A crossed beam system is being developed for use in conjunction with already existing advance data processing and advance statistical analysis techniques. This system will be used to conduct jet noise research by studying fundamental generation mechanics and suppression concepts. Optical measurements are being made of sound source intensity variations in jets by gas and heat injection; these results will be compared with results obtained in full-scale engine exhausts.

Acoustic treatment for jet engine tailpipes.—A study is being conducted to develop acoustic treatment for the jet engine tailpipe. The work will identify acoustic treatment which, when installed in the tailpipe of a JT3D turbofan engine, will reduce the turbine noise and the turbulence generated noise radiated from the tailpipe to a level below the level of the jet exhaust noise. Specifically, the contractor shall perform the engineering design studies, basic experiments, and components tests necessary to determine and evaluate promising alternate approaches to reducing the tailpipe and turbine radiated noise. The approaches are limited to acoustic treatment which can be effectively installed within or around the tailpipe. In evaluating the approaches, consideration will be given to factors such as maintainability, time between overhaul, safety, and cost, as well as engine performance and acoustic effectiveness.

Ground test of the most promising configuration will be conducted by using a JT3D engine equipped with a previously developed acoustically treated flight test nacelle. The ground tests shall consist of noise measurements made in an arc around the engine for several power settings, including approach and takeoff power. Complete engine performance measurements also shall be obtained during these tests. Based on the results of the ground tests, estimates of the acoustic benefits in terms of EPNdb, and change in performance characteristics of a Boeing 707–300B series engine equipped with the modified tailpipe and acoustically treated nacelles will be determined.

Duct technology.—A broad experimental and theo-

retical research program is underway relating to the basic behavior of duct lining materials, the application to aircraft, and the associated operational problems. Basic in-house materials studies include acoustical, structural, and aerodynamic aspects. Flow choking in the inlets of engines involves the use of variable geometry guide vanes and the injection of gases and fluids for localized flow control. The Dynatech Corp. is making systematic studies of water injection as a means of limiting noise propagation in confined spaces. Studies relate to the development of useful prediction methods for noise generation by a rotor in a duct, for the subsequent noise propagation in the duct, and for noise radiated from it.

Studies have involved the flight testing and evaluation of specific duct lining configurations to determine acoustic, and aerodynamic performances.

"Internal" jet noise suppression test.—As a part of quiet engine program, the sources of low-velocity jet noise are being studied. As a start, a J–65 turbojet engine will be equipped with a special tailpipe muffler to separate internally generated noise from the externally generated jet noise. The engine is run at reduced r.p.m. with a 7-foot-long acoustically treated annular muffler attached at the turbine outlet flange. The engine will also be run with an unlined "dummy" muffler section of identical flow geometry for noise comparison. The muffler assembly has five separate modular sections designed to attenuate noise in bands centered at 300, 1,000, 2,000, 4,000, and 8,000 Hertz, respectively. Each module can be replaced by a dummy section.

Other Aircraft Noise

Atmospheric propagation.—A study has been completed to closely correlate flyover noise data recordings, aircraft position information, and atmospheric propagation losses over the audible frequency range. Meteorological studies of the lower 1,000 meters of the atmosphere in several representative locations in the United States are underway to provide a statistical representation of temperature, humidity, and wind gradients; to correlate these with surface observation; and to provide guidance in possible future noise propagation field studies.

Sonic boom.—Considerable effort has been and continues to be taken to study the sonic boom phenomena. Studies are directed toward measurement techniques, analyses of data, meteorological conditioning, atmospheric turbulence, experimental simulation, threshold mach, air stress alteration, operational maneuvers, and modeling.

Engineering development of glide slope computers.—An engineering model of a low-cost airborne glide-slope computer has been developed to demonstrate the feasibility of conducting two-segment approaches for purposes of noise abatement. In addition, this computer has material potential for increasing the operating flight safety level of aircraft conducting visual oral range (VOR)/noninstrument landing system (ILS) approaches to noninstrument landing system (ILS) equipped runways. This is done by adding a command signal to the pilot's vertical guidance. The two-segment approach capability is used on runways with ILS and permits command guidance to be received by the pilot throughout both segments of the noise abatement approach.

Mechanism of noise generation and propagation.—Theoretical and experimental studies are being conducted in such areas of interest as: effects of ground reflection and ground impedance on sound propagation; distribution of noise sources in gas flows; noise of interacting airjets; generation and propagation of sound in helium.

Several mechanisms of noise generation in a supersonic jet stream have been postulated in addition to those dominant in subsonic jets. The means of abating noise generated by such mechanisms may be considerably different and may not be mutually compatible if such mechanisms coexist. Further effort is required to greatly improve our understanding of the noise generating mechanisms from a scientific standpoint, however, due to the current needs for solutions, engineering approaches must be simultaneously undertaken to reduce the airport noise of aircraft capable of operating at supersonic speeds. The research program, therefore, is a three-pronged effort to study the structure, turbulence levels, and associated noise source mechanisms as well as to pursue the two alternative engineering means for supersonic aircraft noise reduction. That is, suppression of the noise generated by the supersonic exhaust is studied through empirical hardware design and tests. Variable engine cycle studies provide for needed takeoff thrust with lower jet exhaust velocities and transitioning to high jet velocity for supersonic cruise.

Funds (in millions of dollars) expended by various Federal agencies for noise in the air during fiscal years 1969–71 are as follows:

	1969	*1970*	*1971*
DOD	1.26	4.18	1.62
DOT	.98	1.93	1.23
NASA	13.12	10.63	13.77
NSF	.03	.11	.10

HUMAN EFFECTS

The human effects category included approximately 4 to 8 percent of the total noise research and development effort.

Physiological effects.—Programs continue to investigate human physiological responses to current and future aerospace acoustical environments ranging from long term, low-level noises to the sonic boom to provide the means to reduce or eliminate undesirable effects.

Continuous noise exposure.—Major emphasis is being placed on the study of peripheral circulation as influenced by noise exposure. Efforts will continue with the intent of quantifying changes and to determine the clinical significance of such findings.

Impulsive noise exposure.—This program is designed to identify physiologic responses that are altered by exposure to impulsive noises and to relate these responses to various characteristics of the exposure stimulus. The relationship between startle and these effects will be established. The role of impulsive stimulus variables with respect to threshold of response, adaptation, and frequency of occurrence will be examined for humans.

Infrasound.—Physiological responses to intense infrasound will be investigated between 0.5 and 30 Hz at levels up to 172 db. Effects on auditory acuity and the tympanic membrane are under study. Exposure conditions which will produce disorientation, respiratory arrhythmias, and other physiologic responses will be defined. The combined effect of infrasound and audio frequency exposures will be determined.

Effects of noise on performance.—Programs continue to measure and define human performance sensitive to acoustic exposures. Short-term memory, manual motor performance, and postural equilibrium in continuous noise exposures continue. Research is supported to determine the sources of natural and man-induced sound patterns which diminish or enhance the physiological health, the mental state, the sense of safety and well-being, and the effectiveness of role performance by man. Monitoring and surveillance activities are supported to determine the characteristic sound patterns and intensity levels that exist in the home and neighborhood area, the work space, and the recreational areas.

Activities in the educational setting are primarily to determine the effects of various sound patterns upon the learning abilities of school-age children.

Research in the occupational setting is aimed at reducing the effects of hazardous sound patterns upon the physical safety and efficiency of the worker. The residential setting is the target for assessing the impact of both mechanical and man-derived sound patterns on human health and well-being.

Acceptability of aircraft noise.—Empirical studies of the relative acceptability of sounds which appear to approach or recede from an observer have demonstrated a significant increase in unacceptability for approaching sources. This phenomenon is being extended through use of actual aircraft flyover or flyby noises.

Personnel protection and communication.—Continuing programs are being conducted to measure and define acoustic environments as required for the evaluation of bioacoustic problems such as personnel protection, communication, siting facilities, and community annoyance.

Frequency resolution in normal and impaired hearing.—The purpose of this investigation is to perfect a simplified manner of obtaining estimates of differential sensitivity for frequency which will study the effects of masking noises and fatiguing sounds on humans.

Auditory communication and its disorders.—Current program is related to clinical audiometry, analysis of processes in the inner ear and auditory nerve, psychophysical studies of masking, and temporal perception.

Determination of susceptibility to hearing loss.—Investigation will assess the validity of temporary threshold shift tests as indicators of susceptibility to permanent hearing loss.

Loudness.—Study distance cues and other parameters correlated with distance charges and measure their effect on loudness judgments.

International standards.—Support is provided the Acoustical Society of America for the establishment of international standards on noise, noise abatement, and other acoustical standards.

Noise disturbance—sonic boom.—Noise disturbance to sleep, public reaction to sonic boom, and environmental influence on public response to sonic boom are being studied.

Hearing levels of residents near airports.—Investigation continues to evaluate hearing levels of residents living near a major airport.

Noise—vision and audition.—Support is provided to the National Academy of Science, Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) for research on vision and audition.

R. & D. is still needed to determine the hearing damage from different noise sources. Continuing R. & D. is required in human response to low fre-

quency noise, personnel protection, communication, and subjective responses to aircraft noise.

Funds expended (in millions of dollars) by various Federal agencies for noise on human effects during fiscal years 1969–71 are as follows:

	1969	*1970*	*1971*
DOD	0.95	0.51	0.60
DOT	.57	.44	.04
HEW	.05	.10	.20
NASA	.76	.72	.70

LAND

Three Federal agencies have R. & D. programs concerned with noise as a pollutant of land media: DOD, DOT, and HUD. Funding by agencies involved was approximately 6 percent of total dollars expended for total noise programs reported.

Land use planning.—An existing FAA computer procedure used for noise exposure forecasting will be modified for military aircraft. A select number of bases will be studied to test the applicability. Future work will involve modification of procedures to apply the forecasting technique to all military aircraft operations.

High-speed equipment.—Studies are being conducted to reduce the noise from equipment with high speed components. These efforts contribute directly to abatement of noise pollution, although the contribution is applicable more to operators in the immediate vicinity of the equipment rather than the general public. Insulation techniques have been developed for reducing noise from high speed generators. This R. & D. effort will be phased out during fiscal year 1971.

Noise exposure site assessment techniques.—In fiscal year 1970, a study was undertaken to provide the technical background for noise abatement in HUD's operating programs. As part of this study, techniques were developed to help facilitate implementation of the proposed HUD policy circular on noise abatement and control. HUD field personnel and applicants, who are not specifically trained acoustical experts will be able to assess present and projected noise exposures at sites proposed for consideration in HUD programs. The screening procedures will be effective in eliminating or decreasing major noise exposure problems before they develop. Additionally, measurement methods using acoustical instrumentation were provided for use in resolving the more difficult situations. A training program consisting of visual aids and an audio tape that demonstrates some of the aspects of acoustics that are important in dealing with community noise and its control was prepared.

Metropolitan aircraft noise abatement study (Logan International Airport).—To develop useful alternatives for achieving both preventive and remedial relief from aircraft noise exposure in the vicinity of a large metropolitan airport. Included are considerations of basic causes, growth trends, and social-economic impact of aircraft noise exposure on individuals and communities near airports. The project includes preparation of alternative approaches for use by local, State, and Federal governments to guide them in land use development, airport development, and related aircraft operational procedures. A methodology for use by other airport and metropolitan planning officials is being developed.

Structural noise.—R. & D. involving generation and interaction of noise with structure components and piping/ducting in buildings, and the performance of acoustic filters is being undertaken.

Urban noise survey methodology.—An effort was begun in 1970 to develop techniques for conducting a comprehensive urban noise study. Comprehensive urban noise surveys will provide the baseline "calibration" of urban noise levels upon which administrative or legislative actions may be based and against which the subsequent efficacy of such actions can be determined.

Acoustical performance criteria.—Design criteria for the HUD breakthrough housing systems were also developed during fiscal year 1970 to help provide a suitable interior acoustical environment free from intrusive noises of neighbors, mechanical building equipment, and noises from outdoors.

Transportation noise study.—To determine the magnitude of the transportation noise abatement problem in the United States and develop a set of analytical tools that can be used to determine the extent of the abatement; provide a comprehensive analysis of the current technical, economic, and legal limits of noise reduction, and estimates of what they may be in the future; determine the level of responsibility (public and private) for noise abatement, and the ability at each level to provide the necessary resources to implement noise abatement program; determine the need for government standards and regulations for transportation noise abatement, to establish specific recommendations for standards and regulations and their means of enforcement; determine the scientific research program which will

maximize the expected return from all related resource allocations; determine how to provide transportation services that stay within acceptable noise exposure in populated areas, given the operational economic, social, and political constraints.

Noise criteria evaluation.—Define and evaluate the noises of transportation with an overall goal of defining the requirements for uniform criteria and objectives for transportation noise abatement—identify and quantify the parameters which characterize differences in the annoyance levels of different sources of transportation—leads to a unified noise rating system.

Interdisciplinary research on the impacts and alleviation of transportation noise.—The specific contributions of this program to existing knowledge is to determine the impact of transportation noise on community, physical, social, and economic environment; to further explore methods for reducing transportation noise by analyzing their effectiveness, impact on system performance, cost, feasibility, and economic desirability; to provide urban planners, transportation system planners and operators, acousticians, governmental agencies, and others with better measures of the community cost of transportation noise, and with better techniques for noise alleviation.

*Subways noise measurement.*Subway noise is being studied by reviewing available technical reports on the mass transit rail systems now in existence in Toronto, Hamburg, London, Berlin, Paris, and Rotterdam and select seven systems that appear to have the lowest noise levels. These acoustical measurements and studies will complement existing data and provide additional data necessary to present a complete matrix of the acoustical environment. This analysis will identify the parameters that define the systems acoustical environment.

Society of Automotive Engineers (SAE) urban noise study.—This study will gather, catalog, analyze and summarize available noise data in three areas, relative to noise associated with the operation of tractors and related equipment. Specifically, the three areas are:

1. Definition of the physical characteristics of typical noises to which operators of such equipment might be exposed;
2. The tolerance levels of such operators, both with and without protection.
3. Degree of possible hearing damage and operator disorientation from exposure to variable noise.

Metropolitan aircraft noise abatement policy studies.—Interagency agreement with HUD to facilitate and extend HUD's research in conducting a series of metropolitan aircraft noise abatement policy studies to consider the causes, trends, and impact of aircraft noise on people and communities near airports is being developed. The purpose of these studies is to formulate applicable alternative policies that may be adopted to guide land use development in a manner compatible with the expected noise levels. Six airport areas were initially selected for study. During fiscal year 1969 research contracts were with:

- New York Kennedy International Airport (Tri-State Transportation Commission)
- Chicago O'Hare International Airport (Northeastern Illinois Planning Commission)
- Bradley International Airport, Windsor Locks, Conn. (Capital Regional Planning Agency)
- Kennedy Regional Airport, Melbourne, Fla. (East Central Florida Regional Planning Council)

As a followup to the prototype studies, a separate project will synthesize the results and make them even more useful to planning agencies. The methodology utilized, the conclusions and recommendations from the completed studies will be evaluated and summarized for potential use in other airport impact situations. The final product from the research will be an airport environs planning manual which will have widespread distribution to planning agencies and local officials.

Clean Air Car Race.—Noise measurements of all vehicles qualifying for the annual transcontinental Clean Air Car Race were made.

Truck tire noise.—An investigation of truck tire noise was initiated in April 1970. The objective of this program is to identify and quantify the physical parameters that affect the noise generation characteristics of truck tires and to develop an information base that may lead to standardized tire-noise testing procedures and to highway noise reduction criteria, standards, and regulations. A requirement for $67,300 in fiscal year 1972 is anticipated to complete this effort.

Transportation noise generation.—Using the aircraft/airport model developed for the Baltimore-Washington metropolitan area, the study will develop and implement a research and demonstration program to measure and evaluate an urban area in the Boston metropolitan area. This will thereby validate and provide more confidence in the methodology used for evaluating noise exposure in urban area.

Modeling for jet noise.—A grant agreement with the University of Southern California to develop

engineering guidelines for the noise abatement of subsonic and supersonic jets. The program of basic research will be conducted over a period of 3 years. The first year's activity will include: (a) the overall design and construction of the research facility: the anechoic chamber, the air supply system for the jet, the jet nozzle, the traversing mechanisms used for detailed measurements; (b) development of special narrow angle microphones of electronic system for data processing; and (c) preliminary measurements in a high subsonic "clean jet." In the second year, plans are laid out to conclude the "clean jet" experiments, to initiate the theoretical study on a source model and to start an experimental and analytical work on the effects of initial conditions. Depending on the progress of this program, it is hoped that in the third year research on the supersonic jet noise problem could be initiated.

Formulation of noise standards.—Efforts continue which deal with the formulation of acoustical standards. The three standards committees of the Acoustical Society (S-1—Acoustics, S-2—Shock and Vibration, and S-3—Bioacoustics) will report upon current engineering and scientific research designed to provide technical bases for specifying standard methods for measuring noise and vibration and defining acceptable limits for noise and vibration by transportation equipment.

Tire acoustics.—A study of tire sound generation whether the variations between tires can lead to an effective acoustical grading of tires. The two distinct areas of investigation are: (a) the physical distribution and characteristics of the sound generated by a representative range of commercial tires under various conditions; and (b) a comparative assessment of the auditory responses to typical noises generated by tires.

Advisory and information services for transportation noise abatement.—To provide for interrelated information services:

(1) Advisory services—information storage, retrieval, and synthesis: an advisory committee within the Highway Research Board of the National Research Council, National Academy of Sciences, of approximately eight experts in the various aspects of transportation noise will be appointed to advise on the scope, sources, and input/output requirements of a storage and retrieval system for noise information and to advise on topics and procedures to be used in the synthesis of stored information and information which is available from other resources. Initial priority for committee concerns is in the area of surface transportation noise.

(2) Storage and retrieval system for transportation noise research information: Develop a specialized file for transportation noise research information service (TNRIS). The service will provide for up to 2,500 references in the first-year operation to cover ongoing research activities, reports on completed research, and publications or other documents within the scope of the service. Output from the system will include response to direct queries, monthly lists and indexes of stored material and, at the end of the contract year, an experimental publication to represent the year's accomplishments.

(3) Synthesis of information for selected topics on transportation noise abatement: After an adequate information base has been acquired, a small number of relatively narrow topics within the field of transportation noise abatement will be selected as high-priority topics for information synthesis. One topic will then be selected for producing a corresponding information synthesis document.

(4) Advisory services research programs: Examine and make recommendations for R. & D. activities that may lead to the implementation, within the transportation community of policies, standards, and procedures for alleviating transportation.

Sonic boom—parks and wildlife.—There is a continuing program for recording sonic booms in four western National Parks. The Federal Aeronautics Administration has supplied mobile equipment which has housed equipment in trailers presently set up at Yellowstone, Mesa Verde, Bryce, and Yosemite. Self-tripping recorders make a record of all sonic booms which impact these areas and tapes are then analyzed. National Park personnel at these and other parks have been alerted to the boom problem and are maintaining a record of all sonic booms that occur within their areas and are noting any physical damage that may have resulted.

Possible damage that may result to marine life from booms impacting streams and lakes is under study. A preliminary analysis of this problem is being made.

Mink are extremely sensitive to disturbance and are an excellent experimental animal to test the effects of sonic boom on wildlife. A number of departments and agencies are cooperating in an effort to determine the effect of sonic booms on mink in Alaska. The results will help in gaging the effects of sonic booms on wildlife.

A need exists to conduct noise measurement, analyses, and information distribution to assist transportation system planners and operators.

Similarily noise measurements and analysis of

ambient noise levels in remote wildlife areas to determine impact of noise on wildlife need to be made.

Transportation system noise measurements in metropolitan areas need to be initiated to gather data that will be used to validate simulation models previously developed.

An investigation of truck tire noise as a follow-on to the current automobile tire noise investigation should be undertaken.

A program wherein highway noise enforcement problems encountered by State and local authorities could be examined to determine areas of possible refinement and innovative methods of noise measurements to assist local officials in enforcing State vehicle noise codes within urban areas.

Surface transportation vehicle noise reduction programs designed to demonstrate economic means of abating noise generated by existing transportation vehicles should be developed.

A program to demonstrate economic and technologically feasible methods of attenuating noise transmissions generated by vehicles operating on highways or other guideways or both is required.

A complete inventory of current truck noise performance and noise reduction kits should be developed. This effort could be used as the first step in the demonstration program on truck noise reduction.

Refinement of mathematical models or transportation noise reduction and attenuation should be developed.

Area-wide planning studies to consider the causes, trends, and the impact of aircraft noise on people and communities near airports should be expanded. The purpose of these studies would be to formulate applicable alternative policies that may be adopted to guide land-use development in a manner compatible with forecast noise levels.

Over the years little has been done to demonstrate means of abating noise generated by vehicles on our highways, hence, little has been accomplished by way of actual noise reduction and many arguments primarily of an economic nature have been made against attempts at State and local highway noise enforcement programs. In addition, the need for mass transit vehicles to supplant the individual auto in conjested urban areas will be taxing a substantial but diffused body of knowledge regarding the design and construction of acoustically acceptable mass transit systems. It is, therefore, necessary, in a priority fashion, to design and develop efforts to demonstrate the effectiveness of current and advanced state-of-the-art noise reduction as applied to surface transportation vehicles. This effort could also explore in a more cursory fashion the economic impact of such noise abatement technology in practice.

Initial effort should be aimed at demonstration projects for the most populous vehicles involved in the areas of largest community annoyance. As progress is made on the vehicles presently creating the largest problem, other vehicles will begin to evolve as the most troublesome, hence, warranting demonstration projects of those vehicles in turn.

It is anticipated that the results of these vehicle demonstrations will permit and become the basis for progressively more stringent State highway noise standards which, in turn, could provide the impetus for the inclusion of technology developed within this research area as routine design and manufacturing practice.

Systematic research and demonstration/evaluation programs should be supported with the aim of properly assessing current practices and developing new and innovative methods of attenuating noise transmission away from transportation rights-of-way. Specific areas to be explored are noise barriers (capable of being added to existing roads and designed into new roads), absorbent materials on retaining walls and abutments, roadside terrain contouring and planting surface material, traffic flow control devices, and other design features.

In addition, techniques to aid highway noise enforcement could be developed to permit such enforcement programs close to urban residential areas and on highways employing noise abatement features.

The results of this research area would provide a direct input to State and Federal highway planners, as well as State highway law enforcement organizations for immediate application within State environmental programs.

A continuing program of research into the more fundamental aspects of noise generation and propagation should be supported as a source of new and more effective concepts of noise abatement theory and technology from which future development and demonstration programs would draw in order to inhibit the escalation of transportation noise in our society. While some efforts will pertain to scientific investigation of a generalized nature with such broad potential application as to preclude indentification of the research with specific transportation vehicles, it is anticipated that end results of all of the research would have specific application to transportation noise abatement and that such applications will be fully postulated.

Contributions of interstate highway noise, airport noise, and major transportation terminal noise to

overall ambient noise levels in urban areas should be further defined by building upon further measurements. Refined measurements would be made in accordance with a detailed plan formulated to insure that sufficient data will be obtained to permit a factoral analysis.

Studies and analyses should be conducted to determine the feasibility of a performing on a continuing basis monitoring of urban noise to further identify contributions made by transportation vehicles. Based upon these results, demonstration programs of urban noise level monitoring could be initiated.

Analytical and mathematical models previously developed should be refined on a continual basis to provide more useful analytical tools for urban planners, vehicle manufacturers, and guideway builders.

Interrelated noise information services need to be provided so that research and advisory information can be made available to appropriate State and local officials to assist in the establishment and enforcement of noise standards, planning, construction, and maintenance activities.

Funds (in million of dollars) expended by various Federal agencies on noise on the land during fiscal years 1969–71 are as follows:

	1969	*1970*	*1971*
DOD	0.10	0.02	0.60
DOT	.93	.15	.46
HUD	.12	.08	.10

WATER

Two Federal agencies indicated an R. & D. effort involving noise in water media. This combined minimal effort totals $66,000 for fiscal years 1969–71, and represents less than 1 percent of the total environmental noise program. The NSF grant supported basic research on sound propagation and has not been funded since fiscal year 1969. The DOT research and development was sponsored by the Federal Aviation Agency and concerned the penetration of sonic boom energy into the ocean (completed in June 1970) and an investigation of underwater acoustic effects caused by atmospheric sonic booms.

Little attention has been focused upon the effects of noise in water. With the concern of the Nation for possible sonic booms effects on flight paths limited to ocean traverse, there should be cause for more scientifically based data of noise and overpressure upon various forms of marine life.

Funds (in millions of dollars) expended by various Federal agencies for noise in the water during fiscal years 1969–71 are as follows:

	1969	*1970*	*1971*
DOT	----	0.04	----
NSF	0.03	.04	00.5

Radiation

For the purpose of this study, radiation was viewed as encompassing ionizing and nonionizing radiation, natural and manmade, which affects the natural or human environment. The radiation programs are divided into the following research categories: (1) evaluation of effects, (2) measurement and monitoring, (3) prevention and control, and (4) transport and fate.

The level of R. & D. effort for fiscal years 1969–71 remained fairly constant at about $70 million per year. In each category the AEC program accounted for more than 95 percent of funds expended. Evaluation of effects received the majority of the emphasis (approximately $40 million per year). Studies devoted to transport and fate of radioactive materials resulted in expenditures of approximately $15 million per year. All radiation programs reported were submitted by five Federal agencies—AEC, DOD, EPA, HEW, and NSF. Funding for each of these agencies in fiscal years 1969, 1970, and 1971 is reported in table 10 (p. 59).

EVALUATION OF EFFECTS

Research in this category enables a better understanding of the immediate and long-term effects of acute and chronic exposure to radiation of various types. Because of the ever-expanding applications of nuclear energy, knowledge of the effects of exposure to low-level (chronic) irradiation is particularly important. Research is carried out to understand the effects and interactions of radiation and other factors on freshwater, marine, estuarine, and terrestrial ecosystems. Investigation of techniques for the measurement of external radiation doses in the vicinity of operating nuclear facilities that release gaseous radioactive wastes to the atmosphere is another program under this category. Dose estimates are being developed from experimental data on tritium and krypton for concentration guides in gas for commercial and domestic use.

Research, including basic and long-term studies involving large numbers of human beings and animals, is conducted to better understand the potential biological effects resulting from exposure to ionizing and nonionizing radiation from many electronic products. Examples of electronic products, which are used by consumers, the medical professions, and in industry, include microwave ovens, color TV's, X-ray equipment, and diathermy equipment among some 30,000 electronic products. Medical and industrial uses of radiopharmaceuticals and radioactive materials are also sources of exposure of immediate concern.

An indoor radon exposure progeny evaluation study is to be conducted to evaluate effects of uranium mill tailings used in construction and surrounding communities. Also of special interest is research to determine the significance of radioactive materials in freshwater systems, since radionuclides are more readily accumulated from the environment by freshwater organisms than by marine forms. Research is also determining the different types of genetic damage produced at the level of the chromosome, gene, and nucleic acids. From such investigations, it is hoped to predict with reasonable accuracy the consequences of specific types of genetic damage in individuals of initial and succeeding generations. Another aim is to understand and predict the impact of specific types of genetic damage on populations, and the mode and rate of elimination of damage from populations. Some of the more specific areas of interest include the study of the effects of radionuclides on plant and animal populations in forests, grasslands, deserts, and tundra and on such biological processes as behavior, food production, succession, migration, and reproduction. Research investigations assess the impact of radiation on soil, plant, and micro-organism ecosystems.

Research in radiobiology is being conducted to evaluate the adverse effects of electromagnetic radiation. A major goal is to develop knowledge of the overall survivability and vulnerability analyses of

systems. Research to define the cause of incapacitation is continuing. Research is undertaken to define laser, microwave, and flashblindness hazards. Efforts continue to develop exposure criteria and protective devices. Funding for R. & D. programs involved with evaluating the effects of radiation accounted for 58 percent of the money in this category. The AEC spent 97 percent of the funds in evaluating the effects of radiation.

Funds (in millions of dollars) expended for evaluating the effects during fiscal years 1969–71 were as follows:

	1969	*1970*	*1971*
AEC	40.98	40.35	39.59
DOD	.90	.82	.82
EPA	----	.28	.78
HEW	2.55	2.69	2.78

MEASURING AND MONITORING

The development of instruments to detect and measure radiation is an important part of the overall program. The development of special radiation instruments to assess uranium miners' exposure to radiation has received much attention. Materials, devices, and techniques for these instruments are constantly being improved. This R. & D. program supports many other Federal activities that assess and control pollution. Related to this work is research in radiological physics, which provides the basis for a full understanding of the underlying physical processes by which radiation produces biological changes. These studies are prerequisite to interpretation of radiobiological effects and to the formulation of advanced dosimetry. Health physics research provides information and techniques needed for the formulation and establishment of improved radiation protection procedures. Detection of low levels of krypton and tritium in effluents from stacks of nuclear fuel reprocessing plants is being developed. Analytical techniques for measuring radionuclides in water discharged from nuclear power plants are being developed. A program to investigate the maximum and average levels of dosimetrically important radionuclides in human diet for use in estimating population dose is continuing. This category accounts for 14 percent of all funds reported involving radiation pollution R. & D. The AEC expends 96 percent of the funds devoted to this radiation area.

R. & D. is required to develop instruments to measure exposure levels of microwaves, ultrasonics, ultraviolet, and other nonionizing radiation, under both laboratory and field conditions, in order to enforce electronic product performance standards. Dosimetry instrumentation R. & D. is also underway.

Funds (in millions of dollars) expended for measuring and monitoring during fiscal years 1969–71 were as follows:

	1969	*1970*	*1971*
AEC	8.72	9.57	9.37
DOD	.20	----	----
EPA	----	.54	.59
HEW	.70	.85	.70

PREVENTION AND CONTROL TECHNOLOGY

R. & D. to improve the collection, handling, treatment, and disposal of radioactive waste materials and effluents from the nuclear energy industry have been important parts of the overall program. The development of improved equipment and procedures for the safe management of radioactive wastes, particularly the high-level wastes from the chemical processing of irradiated reactor fuels, is a major objective. Programs also involve the development of procedures for using alumina to remove or reduce strontium-90 in aqueous effluents from nuclear fuel reprocessing plants.

Evaluation of radon diffusion control measures to determine the effectiveness of ventilation in buildings using uranium tailings for fill material is in progress.

High-power radar and communication transmitters have caused numerous unexpected problems in degrading receiver sensitivity. To avoid this situation, a program is underway to insure electromagnetic compatibility. Funding in this category has averaged approximately $3.3 million for fiscal years 1969–73 and will drop to about one-half this expenditure projected to fiscal year 1972.

Funds for prevention and control R. & D. account for approximately 7 percent of those reported. The AEC expends 99 percent of the funds reported under this radiation pollution category.

R. & D. has been conducted to provide performance standards specifications covering color TV components and shielding, microwave oven interlocks and door seals, and other technical improvements such as X-ray collimators.

Funds (in millions of dollars) expended for prevention and control during fiscal years 1969–71 were as follows:

	1969	*1970*	*1971*
AEC	5.08	4.87	5.12
EPA	----	.02	.03
HEW	.65	.68	.70

TRANSPORT AND FATE

R. & D. programs in this category are directed to the understanding of the mechanisms by which radionuclides move through the natural environment, including inland waters, oceans, and land. Interest in these studies stems from the fact that radioactivity may be introduced into the environment as a result of nuclear energy operations. Among these are radioactive fallout from nuclear explosions, from nuclear reactors for power or propulsion, or from any other situation that might result in the dissemination of radioactivity. From these studies, it is possible to predict more reliably where and how rapidly such radioactivity will be transported. This information is necessary to design procedures to assure that nuclear activities are conducted safely. This category accounts for 22 percent of all funds expended on radiation research and development.

Development of procedures to determine the build-up of radionuclides in a small lake impoundment associated with a nuclear power reactor is currently funded and projected through fiscal year 1971. An evaluation study of radionuclide discharge pathways, techniques of removal, and waste treatment associated with current and planned operating power reactors is in progress and will continue through fiscal year 1971. The basis for determining significant environmental impact of proposed nuclear facilities involves the development of special data from independent studies and problem analyses. Research concerned with the mechanisms of interaction of high-energy atoms of chemical kinetics is being accomplished. Radioactive materials are distributed in the atmosphere and the ocean as tracers of global processes. Projects in the general area of radiation energetics of the upper atmosphere and global distribution of the ozone resulting from photo dissociation and attenuation of the solar beam by atmospheric aerosols are supported. Oceanographic projects are concerned with tritium used as a global tracer. The AEC expends 96 percent of the radiation pollution funds in this category.

The growth of nuclear industries will probably result in increased discharges of radioactive materials to the environment. Current program activities are not sufficient to provide the technical evaluation of proposed power reactors and assessment of the total impact of the operation of these plants on the environment. Intensified efforts should be directed toward development of technology for further reduction of radioactivity discharges. The projected increase in population exposure to krypton and tritium requires R. & D. of technology to reduce and control these radionuclides from power reactors and fuel reprocessing plants. Research on the biological effects of low-level radiation will be needed to expand the knowledge of this effort to improve existing standards. Future use of plutonium as a heat source for space nuclear auxiliary power (SNAP) requires better modeling to estimate its biological effects. Each of the programs identified needs to continue and to be expanded.

There is an increased need for the evaluation of the effectiveness of current and newly developed radioactive waste treatment systems. More study is required to determine the effectiveness of protective actions to reduce population exposure in the event of an incident or accident at a nuclear power reactor. Additional studies are necessary to determine the uptake and distribution of reactor effluent radionuclides in marine ecosystems.

Research investigations are still needed to assess *human exposure* to radiation and to evaluate the impact of radiation upon soil, plant, and microorganism ecosystems. In meeting this objective, models need to be developed for predicting the uptake by, movement through, and loss of radionuclides from components of the environment. Land disposal techniques as alternatives to regulated ocean disposal are needed.

The determination of effectiveness of protective actions is still required. The need exists for nonionizing radiation standards for an expanded frequency range of the electromagnetic spectrum. An accurate, reliable, and portable instrument to measure varying electromagnetic frequencies is still necessary.

Considerable R. & D. effort for many years has been devoted to preventing and controlling the introduction of radioactive material into watercourses of this Nation. The tremendous increase in nuclear energy for electrical power production will require that specific geographic areas where the plants are to be located be studied in greater depth. As ocean disposal of radioactive waste material is phased out, new methods of landbased disposal must be found.

Also of special interest is research to determine the significance of radioactive materials in freshwater systems, since radionuclides are more rapidly accumulated from the environment by freshwater organisms than by marine forms.

It would appear that increased effort and funding is indicated in the prevention and control area. When compared with the level of effort in other categories discussed, the expenditure is dispropor-

tionately small. No long-term solution has yet been designed for the proper disposal of highly active radionuclides.

Voids of knowledge still exist concerning the effects on the human and natural environment for many segments of the electromagnetic spectrum. Little is known concerning high-power low-frequency microwave effects or the significant parameters of concern.

There would appear to be no overlap in R. & D. currently underway by Federal agencies. To the contrary, there appears to be a coordinated effort between Federal agencies to insure that duplication does not occur. Several instances of cross funding between agencies to devote maximum expertise were indicated in this analysis.

Funds (in millions of dollars) expended for transport and fate during fiscal years 1969–71 were as follows:

	1969	*1970*	*1971*
AEC	13.89	15.91	15.11
DOD	----	.01	.01
EPA	----	.27	.96
HEW	.35	.28	.40
NSF	.22	.29	.32

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